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DALLAS, TEXAS
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ANNUAL ENGINEERING REVIEW
MIDYEAR 1932

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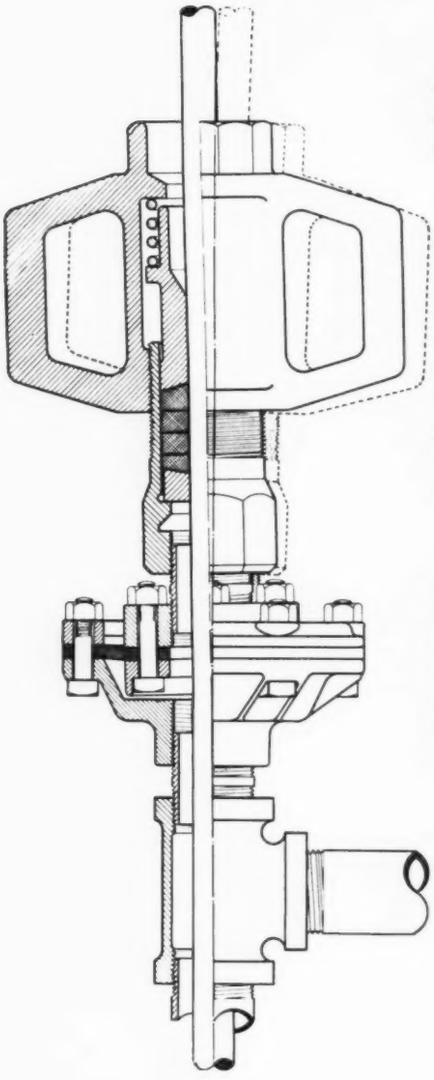

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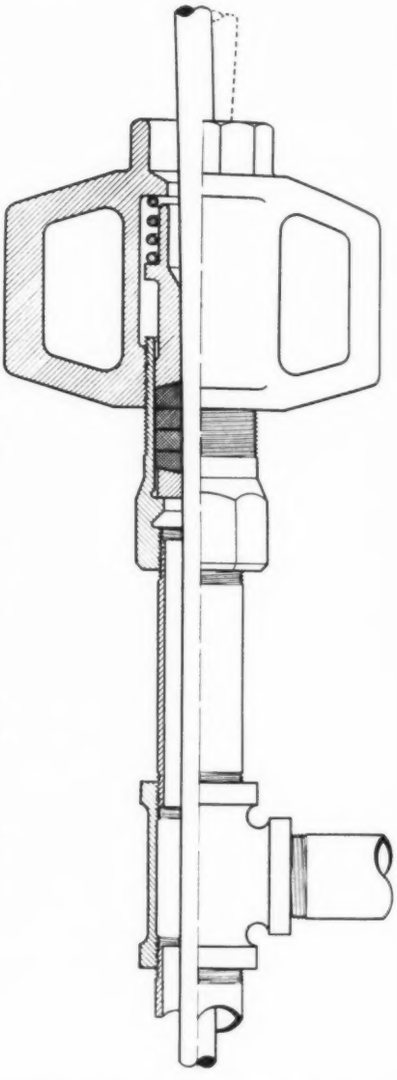

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Our Own *Progress . .*

Since progress is the general theme of this our Third Annual Engineering Review Number, it is not irrevelant to mention here some of the advancements made by *The Petroleum Engineer* during the past year.

Eliciting widespread comment in publishing circles, as well as in the petroleum industry, was the transforming of the magazine's circulation entirely from free to paid within twelve months. This is a record for speed in circulation gathering probably never before achieved in the annals of industrial publication history. Moreover, eighty per cent of the total paid subscriptions resulted from mail solicitation only, and, in no case, did we deviate from our original policy of limiting subscribers to operating men. As a result we were, in March of this year, admitted to membership in the Audit Bureau of Circulations.

The readiness with which our readers responded to the request for paid subscriptions is significant evidence of the important niche *The Petroleum Engineer* has carved for itself. However, we were recently afforded even more direct assurance of wholehearted acceptance through the results of a survey, made by an eastern advertising agency to determine the relative standing of the various oil publications. The frequency with which the magazines are read, the interest they create and their actual helpfulness provided subject matter for the questionnaire and among the operating men (*The Petroleum Engineer's* clientele), we were accorded first ranking, in competition with magazines of vastly greater age.

In the event that you did not realize the full significance of this questionnaire at the time of receiving it, you will be interested to know that it has, and will continue to have, a direct bearing upon the progress of the publications involved.

Therefore we cannot allow this opportunity to escape without thanking each of you readers who had a part in elevating *The Petroleum Engineer* to the top of your particular division. If you chanced to be one who did not feel justified in according us mention, we hope you will take occasion soon to write us, suggesting wherein we fall short. Any constructive criticism will be welcome indeed.

As you turn farther into this issue you will note the new type face in which the editorial matter is printed, as well as the changed headings. We have given the magazine this new dress because we believe you will find its pages easily readable and, at the same time, in keeping with modernity in printing.

Hardly a month has passed since the founding of *The Petroleum Engineer* that we have not adopted some new policy, department or process of printing whereby the value of the magazine has been enhanced. This we have done in fulfillment of our original pledge to spare neither effort nor expense in making *The Petroleum Engineer* as valuable as humanly possible.

Our chief guide in deciding upon the refinements to be made has been the suggestions so generously submitted by our subscribers. These have been of invaluable assistance and we sincerely hope that more and more of you will make known your requirements through an occasional letter. If you are especially interested in some particular phase of production, refining, natural gasoline manufacturing or pipe line work, just let us know and we shall make every effort to obtain an article or series of articles on the subject. Thus your suggestion will not only reflect to your own benefit, but to that of other readers as well.

L. Morris

President

A Review of Oilfield Pro

By K. C. SCLATER

CURTAILMENT of oil production continued to be enforced in almost every oil field during the past year. This is plainly evident in reviewing the progress and trends in oil field production practice during this period. Those practices inviting most attention had as their sole aim the reduction of the unit lifting cost of oil. Among those that might be classed as most important and worthy of discussion here are: coöperative operation in pools, the use of small tapered tubing, bottom-hole choking or beaning, bottom-hole measurements, and the operation of pumping wells and pumping equipment. Oil and gas separation is briefly discussed and also gas-lift and other production systems that show promise of further future development.

Outward manifestations of progress are less obvious than usual, for the nature of the work being done and the improvements under way are not of the spectacular sort. Intensive investigations are being pursued in the field and in the laboratory, toward obtaining a better picture of underground conditions and the changes that take place as oil and gas are withdrawn from a pool.

The year just passed, having been one of the leanest that the oil industry has ever experienced, has compelled producers to turn their attention to more fundamental and effective methods of attacking problems of economy than that of mere retrenchment.

Co-operative Operation of Pools

Many wells of large daily production today are allowed to be produced only at a reduced rate that seriously diminishes the rate of return on the investment. This has had the effect of diverting more attention to the significance of obtaining a low average unit lifting cost over the total life of the well, which in turn has focused attention on the problems incident to prolonging the life of the pool as a whole. In substance, it has enforced upon the producer, a recognition of the principles of coöperative operation of a pool, and created a sincere desire among producers to conform to production practices and methods that will make more secure all equities in the pool.

The relationship between gas energy and lifting cost is now generally recognized, and better understood than was the case two years ago. Proper utilization of gas energy in an oil pool prolongs the flowing life of wells and consequently reduces lifting costs. No longer are wells, even the largest, produced through the casing. From the very day the average well is brought in it is produced through tubing. In flush fields—Hobbs, New Mexico, and East Texas, for example—it is stipulated that all wells when brought in be produced through tubing of a certain size. This was the first step in an attempt to establish equitable conditions in wells in order to gauge their relative ability to produce. Also it was an effort to obtain low gas-oil ratios.

There is apparent a far broader understanding of the principle that by keeping gas-oil ratios within reasonable prescribed limits, the gas energy of a pool can best be controlled and utilized for the greatest common good of the operators in the pool. It is also realized that hydrostatic pressure is an important source of energy in most oil fields, and where present, control of water encroachment is essential in the interests of economy and good recovery.

Gas pressure and hydrostatic pressure are the two components of rock pressure in the average oil or gas field. A knowledge of changes in rock pressure as the oil and gas are produced is invaluable in the practical operation of a pool. Realization of this fact is becoming more evident. Witness the bottom-hole pressure measurements that are now being taken and studied concurrently with the development of the field.

Even now, consideration is being given to the proper penetration and diameter of hole for a well to produce most efficiently and economically during its life. This involves a study of well drainage and the flow of oil into the hole. Bottom-hole data will be invaluable in the solution of such problems. East Texas field, from present indications, will undoubtedly prove a veritable laboratory for sub-surface investigations of this nature.

Along with these investigations, plans have been made, and the work already under way, to run a series of tests on bottom-hole samples of oil and gas to investigate the solubility and the rate of liberation of gas from oil-gas solutions. By making a complete hydrocarbon analysis of the sample of the oil and gas as found in the bottom of the hole, valuable information will be obtained, leading to the proper operation of not only the individual well, but the pool as a whole. With this information the term potential production may acquire a definite meaning, and, it is hoped, lose the stigma attached to it in recent years by reason of the ambiguous methods employed in its determination.

Investigations of this kind are a big step toward acquiring accurate information that will aid in establishing equitable methods of production in oil pools.

Motor Driven Geared Unit pumping two deep wells. The unit is placed midway between the wells and power is transmitted by steel lines.

Bottom-Hole Measurements

One of the recent and most significant innovations in oil field production practice is the taking of bottom-hole pressure measurements in wells at periodic intervals. Only within the last year has real interest in the value of bottom-hole measurements been manifest. Recording instruments of various types are now available for taking pressures in a well. The pioneer commercial instrument, which is of the continuous recording type, is the Amerada pressure bomb. It is in use by several companies in the East Texas field. In the May, 1932, issue of *The Petroleum Engineer* the subject of bottom-hole pressure measurements was discussed more fully than is possible in this article.

Production Practice

SCLATER

So far, the use of bottom-hole pressure bombs has been confined to a comparatively few fields. They were first used several years ago, but inherent defects in the first instruments limited their application for general use. The success of the several instruments now on the market and in use in East Texas and elsewhere has been largely responsible for the widespread interest that is now displayed in bottom-hole pressure data.

Bottom-hole pressure instruments are rapidly coming into general use in the major pools of Texas, Oklahoma and California. The taking of bottom-hole pressure measurements will soon become an important part of routine producing operations.

One of the most interesting of the bottom-hole pressure bombs recently developed is the Alcorn instrument, a product of the Brown Instrument Company. It is run on the bottom of the tubing and is a permanent fixture there while the well is producing. This instrument differs from all the others in that it gives a continuous reading at the surface by means of an electric cable connected between the gauge and a recording apparatus at the well head. The instrument operates on the same principle as the Brown pressure instruments. The angular deflection of a sealed helix in the instrument sets up a vertical motion, which is transmitted to the surface, of an armature moving in an inductance bridge coil. No information is yet available regarding any field tests with this instrument. It should have a wide application in making tests for the purpose of analysing the flowing or pumping conditions in wells.

Some interesting studies have already been made in the East Texas field through bottom-hole pressure measurements. It is revealed that since the restriction of production from the pool a readjustment of rock pressure has occurred. In areas of low pressure the rock pressure is increasing and in areas of high pressure the rock pressure is decreasing. Flowing the wells without restriction the first few months following the discovery of the field reduced the rock pressure an alarming amount in some parts of the field. It was a drastic practical demonstration of the necessity for maintaining a uniform rock pressure in an oil pool. The rock pressure in the East Texas field is now being closely followed by means of bottom-hole pressure. In addition, this information is serving a useful purpose in the solution of operating problems.

A further application of bottom-hole data to operations is in the study flow conditions in the well and in the producing sand. It is probably in this direction that bottom-hole measurements will be found most useful in future production practice.

Tapered Tubing

Considerable progress has been made in the use of tapered tubing to extend the flowing life of wells. Tubing as small as 3/8-inch diameter has been found adaptable to the flowing of small and relatively shallow wells. When a well ceases to flow through two-inch tubing, conditions in the well frequently are favorable for installing small tapered tubing. The success attending such an installation is predicated on a thorough knowledge of the quantity of gas energy available and designing the tapered string of tubing so that it will be efficiently utilized. Much closer study is now being given to the mechanics of well flow than formerly, and the part that slippage and friction play in flowing gas-oil fluids. There is every indication that tapered tubing will be more widely used on small wells in the future.

The use of small tapered tubing also offers attractive possibilities of effecting economies in old fields where repressuring operations are carried on. In such cases, usually there is sufficient energy in the gas injected into the sand and subsequently produced with the oil, to permit flowing wells through small tapered tubing.

Tapered tubing for flowing deep wells continues to be used on an increasingly larger scale. For this purpose, seamless steel external upset tubing in diameters ranging from two-inch to four-inch is commonly employed. The prime object in using large tapered tubing as a flow string is to reduce the gas-oil ratio. For example, in the Big Lake field, the State Railroad Commission required that the gas-oil ratio of the deep wells be reduced, and tapered strings of tubing were installed to accomplish this.

On tests in certain wells in Texas fields produced through tapered tubing, a reduction of 25 per cent below that with straight tubing was obtained. On all sides efforts are being made to obtain a larger proportion of the ultimate recovery by flowing than has been the case in the past. Tapered tubing is one method of accomplishing this, hence its use is quite likely to continue to increase. One thing that has retarded the use of tapered tubing in the past is the lack of accurate information pertaining to conditions in the bottom of the hole and false premises with regard to flow conditions in tubing. This is no longer an obstacle. Valuable data are now being rapidly accumulated on the flow of gas-oil mixtures in tubing. A more extensive use of tapered tubing in wells can therefore be looked for.

Bottom-Hole Beaning

Bottom-hole choking or beaning has undergone rapid development during the past year. Bottom-hole chokes are now available in several different designs. Though they have been in use in a small way for several years it is only recently that they have come into general use for flowing wells.

There are three general types of bottom-hole chokes in use: the removable, the adjustable, and the fixed type. The removable type can be run inside tubing on a Halliburton steel line and set at any desired point. This is the choke in widest use and the one that has aroused the most interest in the possibilities of bottom-hole choking methods. It is not necessary to disturb the tubing to install or remove this type of choke. Originally developed for use in high-pressure gas wells, it is now in great demand for oil wells.

Pumping hook-up in East Texas, showing chemical being injected into a well which is cutting.

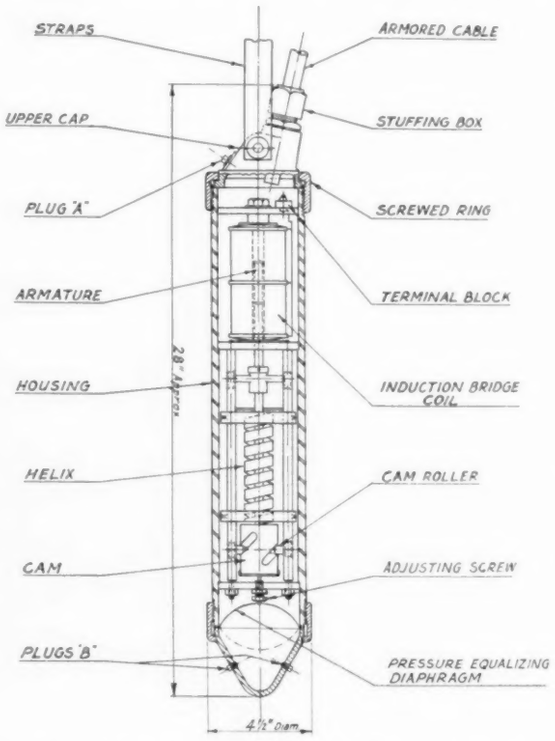
The adjustable type choke is run on the tubing and adjustment is obtained by manipulation of the tubing or rods from the surface. This type of choke is still in very limited use.

The fixed type of choke is run on the tubing the same as the adjustable type, but the size of choke cannot be changed without pulling the tubing. To obtain the proper size of choke it may be necessary to pull and rerun the tubing several times. This type of choke is also in limited use.

Results obtained with bottom-hole chokes indicate that they are well adapted to increasing the efficiency of flow in wells flowing through straight tubing where the velocity of flow at the bottom of the tubing is low, owing to a scarcity of gas in the oil or because of excessive choking at the surface. Good results have been obtained in steadying the flow, reducing gas-oil ratios and increasing the rate of production in wells in the Yates, Cisco, Ranger, and Van fields of Texas. Gas-oil ratios can only be reduced by bottom-hole choking if high gas-oil ratios are the result of low velocities in the tubing. If the natural gas-oil ratio in the sand is too high, then bottom-hole chokes will be ineffective in obtaining low gas-oil ratios.

Quoting from a recent paper,[1] "Experience has shown that the size of a bottom-hole bean for a given rate of production should be considerably smaller than the surface bean at the same rate of production. For example, in one test at Yates, Texas, a 5/32-inch bottom-hole choke produced the same amount of oil as a 3/16-inch bean. A 3/16-inch bean, when placed in the bottom of the same well, produced 20 barrels more oil daily than the surface bean of the same diameter."

An instance of the extremely small diameters that may be used in bottom-hole chokes is cited by this same author. A 4,000-foot well in the Hobbs field with a 3/64-inch bottom-hole choke, produced 60 barrels of oil and 50,000 cubic feet of gas daily. With a 1/8-inch bean, this same well produced 52 barrels oil and 43,000 cubic fee of gas.



Cross-section showing the details of Brown Instrument Company bottom-hole pressure bomb that gives a continuous pressure reading at the surface while the well is producing.

Another practice of interest and of recent introduction is the combined use of bottom-hole choke and surface choke. It is found that the use of a surface choke with a bottom-hole choke under certain conditions is more effective in establishing efficient flow than the use of bottom-hole choke alone.

Bottom-hole chokes have an important application on the siphon lines of gas wells for the removal of water and to prevent freezing of the surface controls.

This removable bottom-hole choke, which shows a wide range of adaptability, can be run and pulled under pressure while the well is in operation and set at any desired depth in the tubing. Its construction is a slip-packer arrangement containing a replaceable positive bean. This type of choke, judging from the results that it has already shown in the field, should play an increasingly important part in the operation of oil and gas wells. It is an effective auxiliary tool in the hands of those who know its limitations as well as its possibilities.

In wells that are bothered with paraffin deposition, as in many of the wells in the East Texas field, doubt is expressed as to the wisdom of using a bottom-hole choke. In order to get some definite information on this point a series of tests are being run on wells to ascertain the flowing temperatures at all points in the tubing, particularly at the bottom of the tubing on the upstream side of the choke and at the surface. These tests are being made at slow rates of flow. Preliminary tests show that there is no perceptible drop in temperature on the downstream side of the bean. The temperature at this point is virtually equal to the bottom-hole temperature of the well, which in the particular well tested was about 152 degrees F. Tubinghead temperature ranged from 77 to 84 degrees F. From these results it would seem that by having the expansion begin at the bottom of the tubing and then gradually take place in the tubing as the fluids rise to the surface, the chilling effect is dissipated to a greater degree than if most of the expansion took place at the surface as occurs when a surface choke is used. It is believed that the high bottom-hole temperature and the heat of the liquid standing between the tubing and casing offset the two-fold chilling effect produced by the expansion of the gas and the vaporization of the gaseous components in the liquid phase. Fear that trouble from paraffin deposition in the tubing will be aggravated by the use of bottom-hole chokes would seem to be groundless if the preliminary tests are at all indicative of what is to be expected.

Well Pumping Equipment and Operation

Although few phases of oil-field production practice have been given as intensive study during the past year as that pertaining to well pumping equipment and operation, innovations in design have been comparatively few. Most of the progress made has been confined to perfecting and modifying the existing equipment.

Oil-Well Pumps.—Pumps of the insert type still continue to hold popular favor. Low daily allowable production in wells has been one factor that has greatly furthered their adoption. Pumps having their vital working parts protected by plating with chromium, a hard metal highly resistant to both wear and corrosion, have been the solution for many pumping problems in localities where severe corrosive and sand conditions are prevalent. Metallurgical improvements in the steel alloys used in pump construction has been a factor in cutting down repairs and replacements. Severe demands are made today on pumps and parts, especially in deep well operation, and manufacturers are constantly on the alert to profit by the failures that occur as well as the successes.

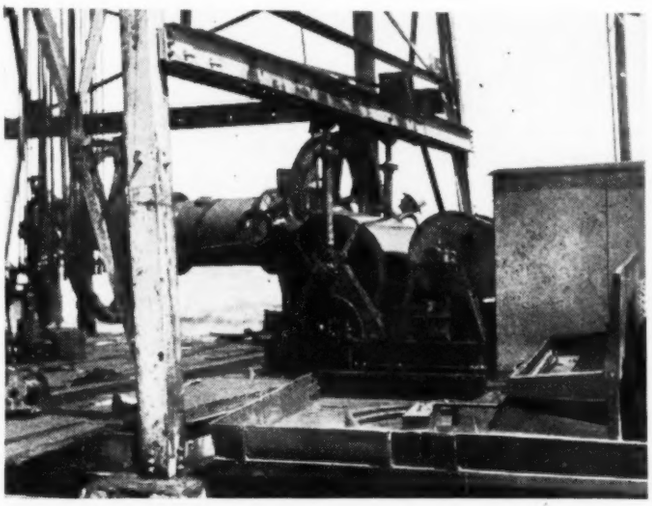
Many of the major companies in the Mid-Continent are regrinding pump valves and seats, either in their own shops or those of the pump manufacturer. Since this practice has started, oil companies are beginning to appreciate the significance of using balls and seats of the proper grade. The savings

[1] "Recent Development and Use of Bottom-Hole Choking" by J. S. Ross. Paper presented before the Petroleum Division A. I. M. E. Houston meeting, October 2, 1931.

effected are dependent on the increase in continuous service obtained. The better the grade of ball and seat used the longer the ball and seat will operate without pulling, and the greater the number of regrindings they will stand. After regrinding they are subjected to a test under 27 inches of vacuum, the same as a new valve and seat. Some companies grind the ball to only one side of the seat, and they find that it pays them to do so as the length of continuous service in the well is increased. If valves or seats are found to be worn or defective when the pump is pulled they are replaced by new or reground valves and seats and the worn or defective valves and seats returned to the shop for regrinding. Delay at the well is cut to a minimum.

Similarly the replacement of worn or defective pumps by a new one or one that has been reconditioned in the shop is made by the pulling crew. The old practice of leaving pump repairs and replacements to the mercy of the pulling crew is rapidly being discarded. Rarely do they have adequate facilities for doing the necessary repair work at the well. All pumps are sent to some central point for repair. Companies find that this method of handling repairs has eliminated a lot of pump trouble and reduced to a minimum the number of pulling jobs.

Much of the success in pumping deep wells is attributed to the adoption of pumps of small diameter. For one thing, they take a load off the sucker rods. Their capacity in deep wells is not affected to the same extent that pumps of larger diameter are, for there is less loss of stroke from rod and tubing stretch. Pumps of the insert type save time in replacements as only the rods have to be pulled. This is a big advantage in deep wells.



Portable Electric Driven, High Speed Hoist for pulling deep wells. Note how hoist is braced against heavy I-beam on derrick by two screw jacks attached to top of drum-shaft bearings.

Illustrative of the progress that is being made in deep well pumping is the fact that in the Santa Fe Springs field, since deep well pumping first started the interval between pump replacements has been increased from 15 days to more than 100 days.[2] This is the result of engineering study. It is also a tribute to the advancement that has been made in pumping equipment.

Vast improvements have been made even in valve cages. Much attention has been given to the design so as to obtain the proper amount of lift that eliminates excessive wear both to the cage and the seat. These may seem minor advancements, but when it is realized that improvements of this nature contribute to the elimination of countless pulling jobs on large numbers of wells, their importance can better be appreciated. Oil companies now keep detailed records of pump repairs so that they can check the service obtained from all vital parts of the pump. Analyses of pump repair costs involve a consideration of all losses incurred by the failure of any part. Besides the material and labor charges, production losses arising from well down-time are taken into consideration. This latter loss frequently is the largest incurred, hence, continuous service in operation with a minimum of shut-down time is the real basis for determining the economies obtained.

Sucker Rods.—Deep wells continue to be pumped successfully with combination strings of sucker rods. The heavy loads encountered have led to this practice. In the Santa Fe Springs field, California, wells ranging in depth from 5,000 to 7,000 feet are being pumped with combination strings of sucker rods. One well in this field is pumping from a depth of 7,800 feet. At this depth the use of combination strings is almost imperative, so great are the loads encountered. The sizes in a combination string range from $\frac{5}{8}$-inch to $\frac{7}{8}$-inch.

Sucker rods are continually being improved to meet deep pumping requirements. Special high strength alloy steels and careful heat treatment are now employed with marked success by sucker rod manufacturers. Internal stresses in the metal resulting from the upsetting operation are removed and the structure of the steel improved by heat treatment. Sucker rod service today, even under the most severe conditions, is immeasurably greater than that obtained several years ago.

The use of wrought iron sucker rods has been revived and is one of the important developments of the past year. Several strings are in operation in 2700-foot wells in West Texas, in a field where severe troubles with corrosion and metal embrittlement are prevalent. The gas produced with the oil has a high hydrogen sulphide content. Pumping wells are quite within the tensile strength of the $\frac{3}{4}$-inch wrought iron sucker rods being used. Apparently much of the trouble due to corrosion and metal embrittlement has been eliminated as they have been giving satisfactory service and have effected economies by their adoption in this instance.

Surface Equipment.—More detailed attention is being paid to suitable surface installations for pumping wells than ever before. It is now general practice to give consideration to methods of operating the well after the flowing period just as soon as a well is completed and placed on production. Low lifting cost is continually kept in mind and is the basis of all deliberations in regard to the choice of pumping equipment. The many excellent pumping units that are now available on the market renders the making of a choice today a somewhat difficult matter.

Surface installations of today are all steel products. For heavy wells steel rig fronts with substantial concrete foundations are being more generally adopted. The latest type of rig front is equipped for an electric drive. It is entirely enclosed and is automatically lubricated, features that make it still more adaptable for field service and reduce the cost of installation, as no building is required. This type of rig front is specially designed for pumping heavy wells from 7,000 to 8,000 feet in depth. Wells 7,400 feet deep are being pumped successfully with this rig front.

The geared power of the enclosed type is increasing in favor. One power of this design recently placed on the market is of the overpull type. It is sturdy and compact in design. The base is an oil-tight bath, which entirely encloses the gears so that they run continuously in oil. A force-feed return system recirculating clean oil lubricates the eccentric bearings and all bearings not immersed in the oil-bath. All gears are entirely enclosed and all moving parts automatically lubricated. Friction, and consequently wear, are reduced to a

[2] "Deep Well Pumping in Santa Fe Springs Field" by B. H. Bobinson. Paper presented before the Division of Production. A. P. I. Chicago meeting, November, 1931.

minimum so that the power can be operated for long periods with a minimum of attention. It takes up small space and can therefore be housed at small cost. Geared powers of the enclosed type are well adapted for desert conditions such as obtain in West Texas, or where dry sandy conditions prevail.

Motorized units having somewhat radical features of design have been developed in California. These are described elsewhere in this issue in an article reviewing California pumping practice.

Improvements in prime movers trend toward increasing the range of service and adaptability so they may be used for pumping deep wells, swabbing, pulling or cleaning out.

One gas engine manufacturer recently has brought out a full Diesel single cylinder, two-cycle, solid-injection type engine with a rating of 40 horsepower at 275 R. P. M. It can be quickly converted to a gas engine. There is a growing demand for Diesel engines for oilfield service and the performance of the relatively few already in the field is being followed with interest.

Manufacturers of internal combustion engines for oilfield service are sparing no effort in adapting their product to meet the ever increasing demands of service as they arise.

Oil and Gas Separation.—This is one phase of production practice that has received scant attention despite its vital importance. In fields of high gas pressure it is sometimes given the consideration it warrants. This is the case in Kettleman Hills field, and several of the other major fields in California. Conditions encountered in Kettleman Hills have been such as to emphasize the important place that oil and gas separation has in production practice. They also convey an inkling of the problems of oil and gas separation that will be encountered in the future development of deep fields.

To those not familiar with deep prolific fields the elaborate trap settings at wells in the Kettleman Hills field are a source of amazement. An insight into the intricacies of oil and gas separation systems are well outlined in a recent paper by R. A. March, presented before the Division of Production of the A. P. I. in Chicago, November, 1931.

Oil and gas separation practice has been, and still is, influenced by the changing conditions encountered in the various fields throughout the country. With the introduction of pressure control methods, and a realization that gas is a valuable source of energy, more attention is now paid to oil and gas separation. In the Oklahoma City field, gas of high pressure and in large volume produced with the oil, accompanied by large quantities of sand, created a hazardous situation that necessitated many new and unorthodox practices and equipment. The oil and gas separator systems evolved, incorporated a sand separation system. An outgrowth of this emergency was the development of dual liquid level controls for the separators. The most recent of these incorporates in its design a diaphragm for regulation of the liquid level. It is now in use on a number of oil and gas separators in the East Texas field.

The trend of future development in oil and gas separation systems will depend largely on the methods that will be adopted of utilizing gas energy in producing operations.

Gas-Lift and Other Production Systems

There is evident today the efforts that producers are putting forth to defer the pumping period of wells as long as possible. Thus, when a well is completed it is operated in such manner that as much of the ultimate recovery will be obtained by flowing or some similar method. For this reason the gas-lift system continues to be an important method of production. Its possibilities for producing deep wells are attractive notwithstanding the fact that curtailment regulations are still in effect.

Modifications of the gas-lift system are being developed. Of these the displacement type of gas-lift pump has shown the greatest advancement. The principle of the displacement type of gas-lift pump is really that of the intermittent system of flowing wells, of which the "Jat" system is the best example. One of the chief advantages of this system of pumping is the fact that a number of wells can be operated and controlled from a central compression plant.

One of the latest pumping devices for deep wells, which has been tried out with some success in California, is a hydraulically operated pump. The pump is of the plunger type and is run on a double string of tubing, usually a 1¼-inch string in a 2½-inch string. It is actuated by clean crude oil pumped from the surface down inside the inner tubing. Automatic valves constructed as an integral part of the pump control the motion. After the oil actuating the pump has done its work, it is discharged into the ascending column of fluid pumped from the well between the inner and outer string of tubing.

Regulation of the oil at the surface controls the number of pump strokes. It is claimed that the surface control is such that the well can be produced at any rate desired up to its maximum capacity.

A test with one of these pumps is being run on a small well in East Texas, in the Joiner area. Here the equipment used at the surface for pumping the oil to actuate the well pump consists of a small high-pressure power pump, driven by a 3- h.p. induction motor through a gear box and a 4-piece tex-rope drive between the gear box and the motor. The pressure on the discharge of the power pump when the well pump was being operated normally, was observed to be from 600 to 650 lb. per sq. inch. This pressure, however, is really higher than was necessary on this well as 1½-inch tubing was being used inside the 2½-inch instead of 1¼-inch tubing. Some trouble with paraffin was also being encountered in pumping the well and necessitated heating the actuating oil at the surface.

Another interesting development in pumping equipment is a pneumatic head. It has been undergoing rigid tests in Oklahoma for several months and is designed for operation on the ordinary type of well being produced by a regular oilwell pump and a string of sucker rods. Operated by compressed air or gas and placed directly over the well, the pneumatic head is equipped with control valves by which the pump motion can be regulated to a nicety. While no information on the results of the tests with the device has yet been made public it is known that the results obtained have been highly satisfactory. It permits a high degree of control, simple of application and accomplished without the aid of a counterbalance. A desirable counterbalancing effect is obtained in the pneumatic head itself and can be adjusted while the well is in operation.

Another development of interest is the plunger-lift pump consisting of a free plunger that travels the whole length of the tubing and is automatically operated by gas pressure. A description of this pump will be found on p. 108 of the March, 1932 issue of *The Petroleum Engineer*.

Combination repressuring and gas-lift systems for the operation of small properties are being given much study at the present time. They seem to offer the dual advantage of increasing the ultimate recovery and reducing the unit lifting cost. In fields where an ample supply of gas is available at low cost and the underground conditions are favorable this method offers attractive possibilities.

Great advancements in production technique are in the making that will have far-reaching effects on future production practice. There is a desire to get down to fundamentals and to pay more attention to underground conditions in the development of a field. This attitude is a healthy sign and one that will make for progress and lead to a stability in the producing branch of the oil industry that a few years ago would have seemed impossible.

Improved Scientific Designs Aid Progress of Refining Methods

By F. R. STALEY

MODERN refining units, remarkable for their efficient and economical operation, are the development of constant engineering research work. Scientific design and the proper application of the excellent engineering materials now commercially available have reduced maintenance costs and shut-down time. Most refining processes are now continuous and automatically controlled by reliable and accurate instruments. American engineering companies, specializing in the design and construction of petroleum refining equipment, have been awarded contracts in numerous foreign countries because of their leadership in the industry.

Strict economy has been necessary for successful operation during the past year, due to the low prices prevailing for gasoline. Many refiners have reduced or practically eliminated freight costs, which have always been a large item of expense. Several major companies, that formerly concentrated their refining operations in one or two very large plants located near the producing fields, have built a number of new refineries or purchased and improved existing ones. These plants are of smaller capacity and are located in important marketing areas, and quite frequently crude oil is carried long distances by pipe line to reach them. A number of Oklahoma and Texas refiners have completed pipe lines for the transportation of gasoline from their refineries to Chicago and St. Louis territories.

Refiners have also saved considerable freight costs by shipping stabilized natural gasoline directly to their bulk plants, blending at this point rather than at the refinery, because of its closer location to marketing areas.

Cracking

The outstanding development in the refining branch of the industry during the past year has been the great increase in the cracking capacities of refineries in all parts of the country. Cracking enables the refiner to meet the growing demand for anti-knock gasoline required for the high compression automotive engine. Units of large capacity, highly efficient, and with great flexibility as to variety of charging stocks have been built. Many more are under construction or are contemplated. A number of these modern units were installed during the year by refiners in Western Pennsylvania and West Virginia, and which are producing gasoline above 76 octane number from Pennsylvania crude.

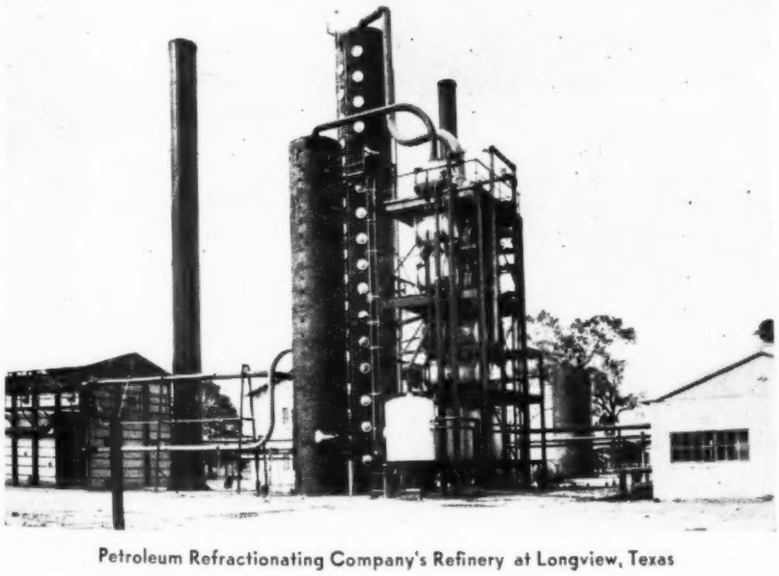
Cracked gasoline is favored over straight run gasoline because of its anti-knock value. Since motor fuels are now marketed according to their octane rating, a premium is paid for high octane products. The modern cracking unit will convert naphtha, kerosene, gas oil, fuel oil, or the entire crude oil directly into anti-knock motor fuel.

A recent development in cracking plant operation is to crack crude oils with high gasoline content directly into anti-knock gasoline, eliminating the skimming operation and the production of straight run gasoline of low octane rating.

By regulation of the cracking process the fuel oil produced can be made to meet various marketing specifications and the production can be controlled according to the market demand. A number of vacuum distillation units have been installed in connection with cracking plants to reduce cracked residiuum to specification asphalt or road oil, this being used in many states for secondary road systems.

The Associated Oil Company, California, completed a 10,000-barrel tube-and-tank unit during the year, the largest cracking unit ever built. Two furnaces are installed, one for cracking and a similar one for viscosity breaking. Each of the reaction chambers, 42 feet long and six feet in diameter, weighs more than 120 tons, and is forged from one piece of steel. The evaporator and the fractionating tower are each ten feet in diameter. The first operation consists of viscosity breaking in which a residiuum is charged and cracked to fuel oil and gas oil. This gas oil is then cracked to pressure distillate. The plant is designed for great flexibility in order to process a wide variety of stocks.

The Standard Oil Company of Indiana is constructing a 20,000-barrel skimming and cracking plant at Whiting, Ind. It will produce only high octane gasoline, gas, and a minimum quantity of residiuum that will be consumed as fuel. No salable fuel oil will be produced.



Petroleum Refractionating Company's Refinery at Longview, Texas

The Alcorn Furnace

The Alcorn furnace has been installed in connection with many of the new cracking units. In this type of furnace radiant and convection heat are separately applied to different parts of the absorbing structure in the furnace. The furnace permits the efficient cracking of a wide variety of charging stocks due to the constant heat input to the oil, and is remarkable because of its simplicity of design and high effectiveness. It yields high octane gasoline without excessive gas losses and objectionable gum formation.

The owners of the Dubbs cracking process have reduced the royalty rate for viscosity breaking by this process and charge no royalty for the straight run gasoline content

of the crude run to cracking units, providing this gasoline is not subject to cracking conditions. This company has made available to licensees a special royalty rate to cover cracking or reforming of straight run naphtha boiling to 400° F. The new rate for viscosity breaking applies mainly to very viscous oils where yield of gasoline is not important but the purpose is to reduce the viscosity to meet specifications.

Stabilizing Plants

Most refiners have installed highly efficient vapor recovery and stabilization plants in order to retain the valuable light fractions produced by the cracking process, and to control the vapor pressure of their finished motor fuel. This type of equipment had been developed to a very high degree of efficiency in the natural gasoline industry, and the refinery plants were usually built by the same engineering companies. Fixed gases from the cracking processes possess a high calorific value, and are used as refinery fuel or sometimes as excellent raw material in the manufacture of chemicals and alcohols.

Octane Number

The octane scale is now generally used for expressing anti-knock value. The method for determining the octane number of motor fuels has not yet been adopted as a tentative standard by the American Society for Testing Materials. A committee of this society has prepared a description of the method based on the work of the Coöperative Fuel Research Committee, which is jointly sponsored by the Society of Automotive Engineers, the American Petroleum Institute and the National Automobile Chamber of Commerce. The Ethyl Gasoline Corporation's Series 30 Knock Testing Engine is now generally used to determine knock rating.

Ethyl Gasoline

On March 1st the minimum anti-knock standard of Ethyl gasoline was raised from 74 to 78 octane number. This gasoline is now available to motorists throughout North America. The new standard meets the peak requirements of the highest compression engines on the market today and will bring out their full performance. Equipment for blending Ethyl fluid with gasoline in large volume, with a high degree of accuracy, has been developed by engineers with this company. Ethyl fluid is now shipped to blending stations in special tank cars. The Great Lakes Pipe Line Company has installed six new Ethyl blending plants at various marketing points.

Fuel Consumption

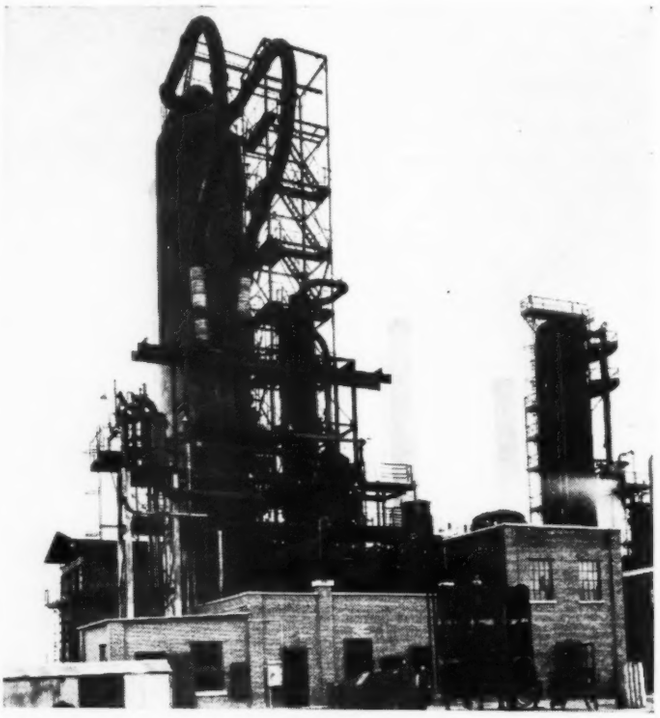
The consumption of electrical power by refineries during the year 1931 has increased considerably over the previous year, according to the United States Bureau of Mines. Several refineries are now operating entirely with electrical power.

Great progress has been made by motor manufacturers. Motors especially designed and approved by the Underwriters Laboratories for service in hazardous locations are now available, and have resulted in a greatly increased number of motor-driven refinery pumps. Explosion-proof motors are used on gasoline pumps and totally enclosed fan-cooled motors for out-door installations. Explosion proof motor starters have likewise been developed to meet the requirements of hazardous locations.

Automatic start and stop plants that provide freedom from shutdowns resulting from power disturbances, are increasing in importance. An interesting development has been an instantaneous unloader for synchronous motor-driven ammonia compressors. The unloader, in conjunction with the automatic control for the motor, makes the by-passing operation of the compressor entirely automatic.

The annual survey of the United States Bureau of Mines showed that refiners made steady progress in fuel economy in recent years and that they are using more of their own products for fuel. Pulverized petroleum coke, acid sludge, refinery gases, and slops, for which there is no profitable market, are now being used economically at the refinery.

The report mentions some of the important developments in refining that have reduced fuel consumption, including the universal installation of pipe stills as primary distillation equipment which has greatly increased thermal efficiencies. Pipe stills are now used for atmospheric or vacuum distillation.



A Modern Distillation Unit

The heat exchanger is another economizer of refinery fuel. It was first used to transfer heat from the hot residiuum to the incoming crude; later vapor heat exchangers were developed to utilize the heat from the hot vapors, and to reduce the load on the condensers.

Tremendous progress has been made by engineering companies in the manufacture of heat transfer equipment. Successfully operated high pressure exchangers are now built for 830° F. and 1,000 to 2,000 pounds operating pressure.

According to a prominent manufacturer the considerations involved in determining relative efficiency of heat transfer apparatus are: (1) heat load capacity per unit of weight, bulk, or cost; (2) terminal temperature difference between the two fluids handled, and (3) loss of pressure in the fluids in passing through the apparatus. Such factors as tight and effective baffles, arrangement of fluid passes, venting, tube layouts and compactness of the unit are details that must be considered in selecting this type of equipment. A few years ago heat exchangers were considered in the luxury class, but now they are given careful attention in the design of any unit.

The necessity of efficient insulation is generally recognized by refinery engineers and it is extensively used on high or low temperature equipment.

Important savings in fuel can be effected in refineries in many ways: by improvements in furnace design through automatic control, improved insulation, and by efficient operating practice. The elimination of the human element by

reliable automatic controls has effected savings in many cases.

Welded Equipment

Welding of field and refinery storage tanks without limitation as to size has been successfully developed, and it is also used in the construction and fabrication of other refining equipment. Thick-walled welded vessels have been accepted for the extreme conditions of pressure and temperature required in cracking processes.

In a paper presented before the A.S.M.E. in Tulsa, G. Raymond outlines the reasons why welded pressure vessels are generally accepted by the petroleum industry:

1. *General improvement in the quality of all welds.*

The vigorous pioneering efforts by a few leaders of the industry have greatly improved welding process technique, which efforts have enabled them to produce welds of remarkable ductility, strength and high quality.

2. *The entire leak-tightness of welded vessels.*

It is now generally recognized that a welded vessel, properly constructed, will remain bottle tight up to the pressure of its ultimate failure. Leakages, or seepages, are particularly hazardous in the petroleum industry where the fluid contained in the vessels is so likely to be at a temperature higher than its flash point, so that even a slight leak almost always means a flash into a fire, which may do destructive damage to any piping or structures within its path, and easily start a general conflagration.

3. *Corrosion resistance.*

The resistance to various forms of corrosion of the modern quality weld is practically equal to, and in many cases superior to, the mild steel plate material joined. This is in high contrast with the older methods of welding.

The bottle-smooth interior surfaces of a properly made vessel, all of whose joints are butted, allows little or no opportunity for crevices to start cracks by aid of caustic embrittlement, an important considertion in the steam generation field.

5. *Ability to construct vessels of great thickness.*

The ability to produce quality vessels of two, three and four inches, and even greater thicknesses, did much to stimulate the use of welding in the pertoleum industry, as such thicknesses were early demanded by high pressures, high temperatures, and the corrosive effect of various cracking processes.

Extreme demands for large pressure vessels capable of withstanding pressures up to 450 pounds concurrently with temperatures up to the extreme of 920° F., together with corrosion and shock factors, were largely responsible for the great impetus given to quality welded construction.

Refinery Valves and Piping

Better valves are now being manufactured to especially meet high temperature, large pressure and corrosion conditions encountered in refining.

The joint Research Committee on the Effect of Temperature on the Properties of Metals arranged a symposium last year, and the data has been published in book form jointly by the American Society for Testing Materials and the American Society of Mechanical Engineers, affording a ready reference to information on the effect of temperature on metals. Heat and corrosion resisting steel pipe and tubes are now widely used in refining units. A group of heat enduring materials have been developed specifically for oil refinery service. The physical properties of each alloy over its entire operating temperature range are presented in this book, enabling the engineer to design structures for high temperature operation with the same facility which attends ordinary structural design.

Treating Methods for Cracked Gasoline

Many different methods have been devised for treating cracked gasoline. The gum forming constituents and other objectionable compounds must be removed without lowering the octane rating. The quantity of sulphuric acid used in refining has shown a decided decrease since anti-knock rating has become important.

One of the most economical and successful methods of refining cracked gasoline is the Gray Vapor Phase Process, which can be used in connection with any type cracking unit. This process produces a stable gum-free gasoline with no loss of octane number.

Several methods to control the sulphuric acid treatment are in use. The Standard Oil Company of California uses refrigeration in order to reduce the treating temperature. In the Stratford process a mechanical contactor is used to obtain intimate contact in minimum time.

Lubricating Oils

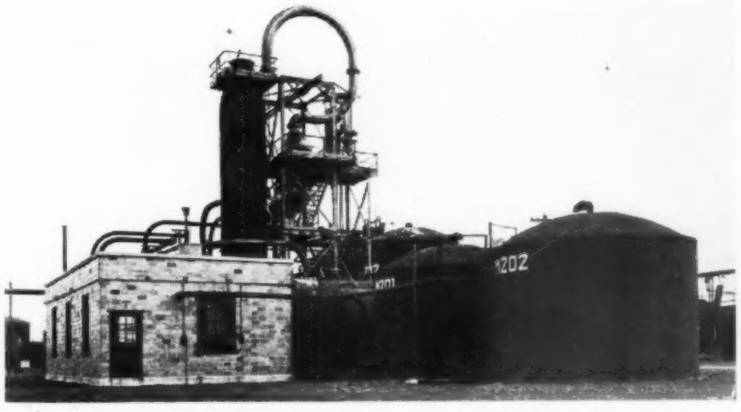
Specifications for free-wheeling lubricants have been proposed, but formal adoption by the Society of Automotive Engineers has been postponed temporarily. Mougey and Almen discussed extreme pressure lubricants before the American Petroleum Institute meeting in Chicago. The automobile manufacturer cannot produce gears requiring special lubricants until such lubricants are universally available. The problems that are involved are too great to be solved in any reasonable time by any one individual or company, but will require the coöperation of all industries affected.

Petroleum Chemistry

More and more refining is becoming a chemical industry. Petroleum is a valuable source of raw material for the manufacture of a great variety of products. H. M. Smith of the United States Bureau of Mines outlined to the Western Petroleum Refiners' Association the various methods that can be used for manufacturing chemicals and other industrial materials from petroleum. Steady progress is being made in chemistry knowledge of petroleum.

Foreign Refineries

The United States Department of Commerce recently published a report on petroleum refineries in foreign countries. Five years ago foreign oil developments seemed to be of little importance to the American petroleum industry, but within the past few years considerable attention has been attracted by foreign oil production and refining. Recently the increase in the number and capacity of foreign sources of crude petroleum and improvements in refinery technology have contributed to the establishment of refineries in many foreign countries.



Vacuum Distillation Unit for Processing Cracking Plant

Improved Methods and Materials

By J.H.

ALTHOUGH the past 12 months was not a record breaking period from the standpoint of mileage of pipe lines built, it was characterized by improvements in design and construction and operating methods. The world's longest and largest diameter gas lines were built and placed in service; several important changes were made in oil line pumping practices and the industry witnessed a great change in the distribution of refined gasoline with the completion of a half dozen major gasoline lines.

Contributing to such advancement the oil industry was afforded greatly improved materials with which to work. Contractors, in turn, had devised speedier and more reliable construction methods with the aid of heavier and sturdier-built machinery. Taking advantage of these factors, designing engineers were able to reach into more distant markets with pipe lines, assured of more reliable construction at a lower cost, as well as higher operating efficiencies.

The history of manufacturing improvements in line pipe is generally known but, since the building of the Interstate Pipe Line Co.'s 170-mile 22-inch coupled line from the Monroe, La., field to Baton Rouge, pipe mills have perhaps made their greatest strides in improving their products. That line, built in 1926, was the first major large diameter gas line. Its construction opened the way for the expansion that has been witnessed in the gas industry since that time.

During this period electrically welded pipe and seamless pipe up to and including 24-inches in diameter were offered to the industry. At the same time the tensile strength of the material was raised by the use of higher carbon steel, bringing about thinner wall and lighter weight pipe. Today manufacturers deliver pipe with an ultimate tensile strength of between 70,000 to 80,000 pounds per square inch.

With pipe of improved quality, main lines that formerly reached their limits at 100 miles are now built to terminals 1,000 or more miles away. Utilizing the high tensile strength of the pipe many operators have gone to higher operating pressures. Some of the more recently constructed gas lines are operated with pressure up to 800 pounds.

Since a line is no stronger than its weakest joint, it follows that welding and coupling manufacturers kept pace with developments in the line pipe field. Today the industry is offered welding material and equipment for both acetylene and electric welding that will make a weld testing as strong or stronger than the parent metal. Couplings have been improved also to the point where they easily withstand most severe pressure tests.

Steel mills deliver pipe for most projects in 40-foot lengths, or longer. These are designed for all types of joints, double bell ends for use in connection with chill rings, bell and spigot joints and plain ends beveled for welding. On most of the large diameter lines composite construction is employed. Either the line is joined with an alternate weld and coupling or several welds and a coupling.

Up to the present the largest diameter pipe used by pipe line companies is 26-inch. This diameter pipe has been used in the construction of major lines both on the Pacific Coast and in the Mid-Continent. The industry may be offered a still thinner walled pipe with a higher tensile strength than is now made, according to reports from manufacturing centers. That lines of still larger diameters may be expected in the future is indicated by the plans of one company to use 30-inch diameter pipe in the construction of its next trunk line.

Staying abreast of developments, the manufacturers of valves and fittings are offering better built products giving greater safety and more efficiency. Newer and improved types of valves are offered for station and field service that have suitable fittings for welding. The radius bend is used more extensively than ever in station as well as field piping.

To obtain greater construction speed without sacrificing quality, pipe line builders have met the demands made upon them by constantly improving their methods. Manufacturers of machinery have aided greatly in building large, heavy-duty, ditchers, tractors, cranes, power shovels, trucks and the scores of other pieces of pipe line equipment.

In most instances, this has been a matter of enlarging the equipment used on a smaller diameter line. Improvement of the equipment within the past year has been chiefly confined to the refinement of machinery. Today machines are built to withstand hard usage in all kinds of weather. Moving parts are totally enclosed so far as possible both as a safety measure and to keep dirt and moisture away from bearing points.

The larger lines, of course, have called for deeper trenches and whenever the big ditchers encounter rock they are moved out of that area and replaced by powder crews, powerful shovels and cranes with clam shell attachments. By using the latter two types of machines ditching problems that formerly were time consumers and costly are now ones not causing any serious delay.

Crews working under the guidance of experts in blasting use a small fleet of portable air compressors to drill shot holes. Charges of blasting material are placed over long sections of the

Crane lifting 26-inch pipe while building Northern Natural line in Kansas

Permit Expansion in Pipe Line Work

DAMERON

right-of-way and the entire section is blasted at one time. As the blasting crews move forward the big shovels are brought in to remove the shattered rock and "dress" the bottom of the trench for the pipe.

Blasting has been extended to ripping out a trench for the lines in a stream crossing. Properly spaced charges are lowered to the river bed and exploded. This same method has been used in making trenches through swamps where it would be impossible to operate a ditcher.

The big shovels along with large tractors have been employed with great success in clearing the right-of-way. Working a considerable distance ahead of the stringing crews this equipment cuts roadways and in many places levels off the ground to save small bends in the line.

The cranes with the clam shell attachments have a wide range of use. Under ordinary conditions they are used to lift large diameter pipe in various phases of field work. They are frequently used to unload large pipe from cars and onto stringing trucks.

In the building of stream-crossing approaches this piece of equipment has often been a time saver. It is also useful in quicksand areas in mucking out caving ditches as pumps remove the water.

Perhaps one of the most noteworthy advancements in line construction has been the practice of making bends. On pipe of large diameter, made of high carbon steel, some of the companies have used "tailor made" bends. Other companies have chosen to make field bends on pipe as large as 26-inch.

This has been done with success under the direction of engineers and skilled bending crews. The former calculate the exact degree of bend required and the bending crews so control the heat applied to the pipe and the steadiness of the pull made on the section to be bent, that failures are rare.

Another of the noteworthy developments in construction methods has been the development of a lowering horse with a swinging leg and a winch on the A frame side. The winch is of a type permitting a close control during lowering operations, eliminating sudden jerks and stress on the welded or coupled joints. The swinging leg on the lowering horse permits a specially built boom on a truck to pick up the lowering horse and move it to a new location with greater speed.

Each horse has its operator who travels on the truck from one location to another. When the swinging legs on the lowering horse is free it falls in against the A frame making the unit less cumbersome to handle in the field or in transit. With this method (which was developed some time ago but not used extensively until the past year) five or six lowering horses may be working while one or two are moving forward. The truck with the special boom serves as a shuttle train, running in forward speeds in moving to a new location and returning in reverse gear.

Numerous improvements have been made in the application of protective coating to the lines. To meet insistent demands for clean pipe before the application of priming paint, air-driven cleaning machines have been developed. These are powered by portable compressors and the small cleaning machines impart a bright finish to the pipe which is immediately coated. Some companies use spraying equipment to apply priming coats.

In the application of most coatings the pipe is rotated by a hand or power-operated rolling rig. Material is applied by means of pouring buckets and its thickness governed by spreading pads used by a workman, or with pad-equipped buckets. A number of builders use compressed air-powered motors to drive their rolling rigs and some have trucks equipped with a power take off to rotate the pipe on rollers. By this latter method the thickness of the coating is controlled by the speed of rotation.

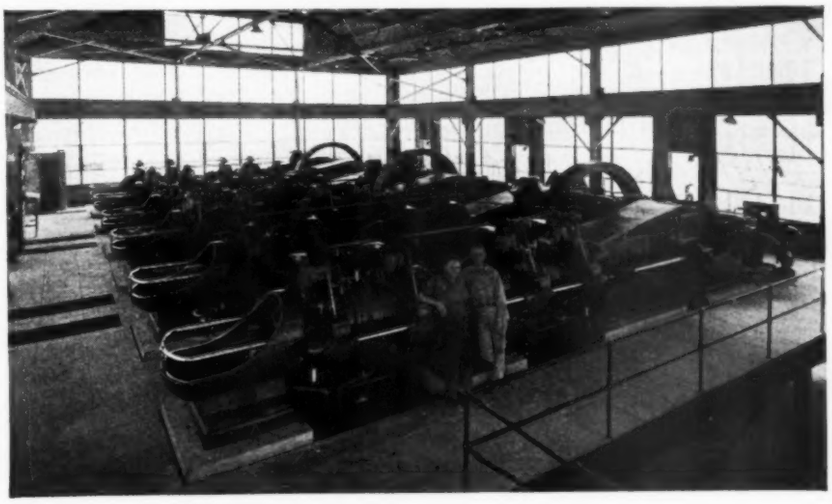
Closer attention is given to control of temperatures of hot coating material in the heating kettles. In most instances instruments are used. More attention, too, is given to the prevention of breaking the coating when the line is lowered into the ditch. One of the most recent developments in coating has been the baking of an enamel application on the pipe at the mill.

Coating lines with concrete in the "hot spots" was a practice followed more widely last year. This followed the development of a vibrating machine which permitted the uniform application of a dense mass of concrete about one inch in thickness around the pipe.

With the succession of large building projects the past few years pipe line companies have improved their methods of making highway crossings. Boring machines have been improved and, by their use, crossings are made more economically and faster. Their use, however, is restricted to the smaller diameter pipe. When highways are crossed with large diameter pipe the road repair is made with tamping machines, a piece of equipment becoming standard with several contractors.

Methods of maintaining construction equipment and supplying small parts to scattered crews building a major project have undergone a change. Numerous builders start a project with a centrally located warehouse and operate it with an organized delivery system.

Light trucks are started from the warehouse each morning



Interior view of a modern compressor station

to deliver supplies and parts along the line. As the deliveries are made the drivers ascertain the material needed by the crews for the following day. Equipment maintenance men order their material when the truck arrives and dull cutting steel is exchanged for sharpened steel. The dull steel is returned to the warehouse shop which also handles most of the construction crews' shop work. In the event parts are needed sooner than the pick-up trucks can deliver them the parts are obtained by sending one of the trucks in from the nearest crew. By following this method several companies have been able materially to reduce their warehouse charges and maintain equipment to better advantage.

Another of the interesting developments of the past year has been the building of pipe line bridges on an extensive scale. The Northern Natural Gas Company completed its main line system last year and 16 major bridges were included in the construction program, along with numerous small bridges.

The longest of these is a 3,156 foot suspension bridge over the Canadian river near Borger, Texas. From an engineering viewpoint the building of a 1,280-foot single-span bridge over the Missouri river at Sioux City, Iowa, was perhaps the most interesting. In cost, the bridges compare favorably to the multiple line submerged crossings. Making a crossing on the bridges has the advantage of leaving the line always available for inspection and repair and not subject to the hazards of the submerged lines.

Notable advancements have been made in the laying of submerged river crossings. The Prairie Pipe Line Company laid two 10-inch lines simultaneously across the Mississippi river with a ramp barge. This was accomplished by lashing two barges end to end and building a ramp inclining to about 22 feet. Steel trackage was built the entire length of the ramp. Three 80-sections of pipe were lined up and welded on each of the two sets of trackage. When the lines were ready to be lowered the ramp barge was moved forward, letting the pipe go down at an angle and imposing less bending strain on the pipe during laying operations.

One of the most interesting of the stream crossings made was the building of an under-water tunnel beneath the Houston ship channel by the Sinclair Texas Pipe Line Co. Vertical shafts were sunk on each side of the ship channel and these were connected by the tunnel beneath, making a U-shaped crossing. The tunnel and shafts were built with re-enforced concrete and made large enough to permit workmen to have easy access to any part of the crossing lines.

Improved methods of welding have made it possible for pipe line companies to expect a longer period of service from their lines, at a diminished maintenance cost. Rapid strides have recently been made in the repair of old lines by taking them up, cleaning them and spot welding the pits.

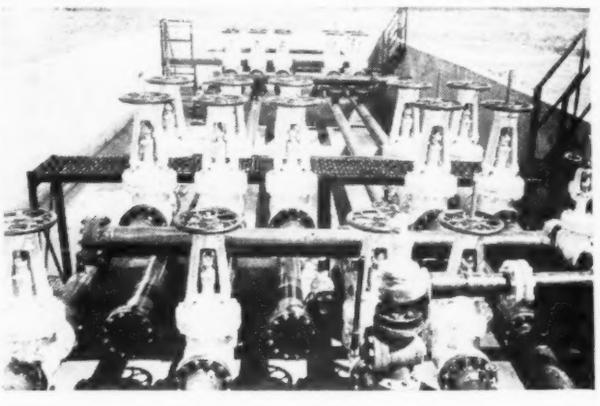
Should a length of pipe be badly pitted a half-sole is made by cutting a suitable length of larger diameter pipe longitudinally and welding the elongated split sleeve to the line. Under ordinary conditions the pits are thoroughly cleaned, circled with chalk to facilitate the welder's work. The welder fills each pit with a spot weld. In the event of a too badly pitted length the pipe is replaced with new material. Leaks around the screw couplings on old lines are repaired by means of shop-made split sleeves fitting snugly around the coupling and welded to the pipe.

A combination cutting and beveling machine was recently developed to be used when old or abandoned lines are taken up. With this machine the joints are cut out of old lines and, by adjusting the torch, the cut is made to any angle desired, eliminating the necessity of beveling the pipe in the field or warehouse after the joint has been cut out.

A succession of changes in station planning and operation has brought about still further economies on both oil and gas lines. Many of the newer type of natural gas compressor stations are full basement stations which permits doing away with pipe conduits. All gas, air, water and lubricating oil lines are located in the station basement, making them readily accessible for changes or repairs. Most of the lines rest on steel pegs in walls of the basement.

To lower friction losses and make otherwise difficult bends in station piping radius bends have been used to a wide advantage. These fittings have greatly improved the appearance of station piping, as well as making for improved installations.

Newer stations are designed to take advantage of the more improved methods of lighting, ventilating and heating. Station lighting systems are now designed to eliminate shadows and dark corners at night and the ample window space provides more natural lighting. Many stations are equipped with radiators and blowers which circulate the warm air to all



Above: Manifold at gasoline pipe line station

Left: Unloading large diameter pipe from freight cars to stringing trucks

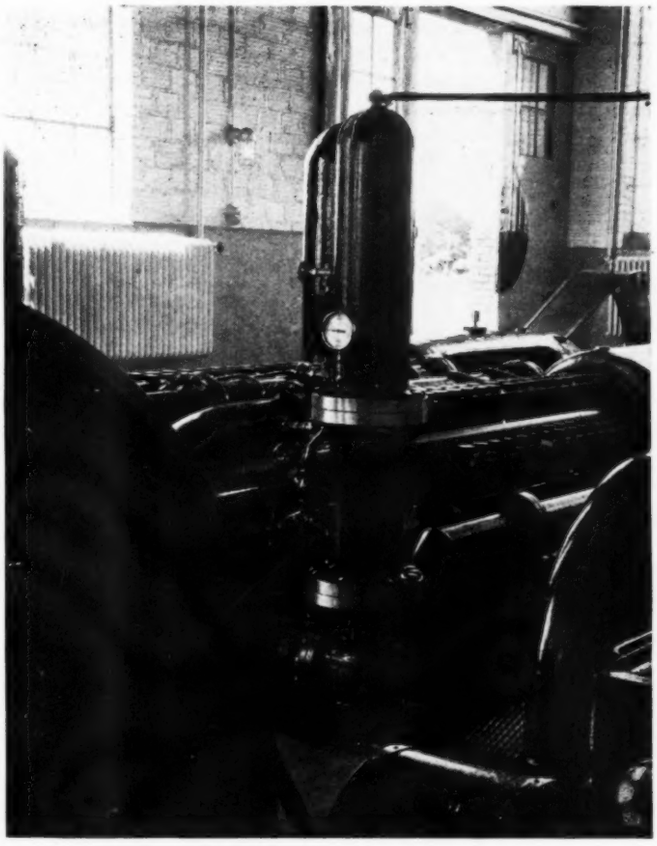
parts of the station and at the same time keep fresh air in constant circulation. Some of the stations use the blowers to circulate air during the summer months to lower the interior temperature.

Both gas engine driven compressors and oil line station equipment have been improved in many details, and this increases the efficiency of the units and promotes safety. Equipment is better in design than in former years from the standpoint of making repairs. More consideration has been given to station design with the view of allowing ample room for repair crews to work on the machinery.

The new units' improved design also has taken into consideration the enclosing of moving parts for safety. In most of the pipe line stations today all moving parts are guarded by shields or railings of various designs.

Construction of pipe line station floors is another phase of station building to be given more attention. More thought has been given to the proper mix of concrete for floor surfacing and much study and research work have been carried on to determine the most suitable paint with which to finish the floor. Several companies use colored wax or a special wax over a painted floor. While the latter method requires more work on the part of the operating crews the wax floors apparently withstand the severe service and are impervious to oil leaks. Wax imparts a more glossy finish and improves the appearance of the floor.

New and improved control instruments for use in pipe line stations have given transporting companies closer and more accurate control of stations. This has been particularly true in the field of automatic and semi-automatic stations, and these same installations have made for safer operation. With them units may be automatically cut out when abnormal pressure limits are reached or when a unit is running with excessive bearing temperatures.



New type air chamber used on reciprocating pumps

Gauge boards today are built in units with manifolded piping permitting the cutting out of any panel, whenever desired, without disturbing others. The boards may also accommodate instruments used in connection with checking the operation of engines and pumps. All of the better grades of instruments are built to withstand severe service and have facilitated much of the research work carried on by pipe line companies.

The largest gas engine driven compressor station yet built was constructed last year. Natural Gas Corporation of America established this mark with the completion of its Fritch, Texas, station, housing twelve 1,250 horsepower twin tandem units. The 15,000 horsepower plant is the initial station on the 175,000,000 cubic foot capacity line terminating in Chicago, Ill.

One other development of the past year was the operation of a turbo blower for main line work. One of the major gas transmission companies installed a motor driven turbo on its line in Kansas. This is housed in a steel shell and tied directly into the main line. Gas passes through the motor in one end of the shell where its pressure is boosted by the turbo-blower and delivered into the main line, flanged to the other end of the shell. The unit is said to have passed a satisfactory test run during winter months.

In the oil and gasoline pumping field several important developments have been made. Automatic station operation by remote control was further improved and the first attempt to operate an oil line by a pressure-volume differential was made with success. Skelly Oil Company built such a booster station on one of its Kansas Lines.

Its operation is controlled by a flow meter in connection with electric switches. When it is desired to start this station, pressure is dropped and flow reduced by cutting out a pump at the station behind. This may be accomplished by the manipulation of a gate valve on the centrifugal pump. When a predetermined volume at a lower pressure is passing the booster station the flow meter actuates the electric starting devices, which, in turn, start the motors driving the centrifugal pumps.

With the booster on the line the operator at the station behind it observes the dropping of discharge pressure. He immediately starts another unit in that station or opens the discharge gate on the centrifugal pump. To stop the station, pressure and volume are again lowered.

This type of station will operate only on one pressure-volume setting or value. This value, however, may be set to conform to a wide range of operating conditions by changing the instrument settings at the station or by blocking out one of its two centrifugal pump units.

To obtain a wider range of operating pressures at stations utilizing centrifugal pumps, some of the oil transporters have installed pumps of varying capacities. Common practice is to install pumps to deliver a desired volume at a given pressure. Should it be necessary to reduce runs it is necessary to pinch down of the pump discharge gate with a high loss of efficiency for the unit.

With units of varying capacities the oil dispatcher could glance at a prepared chart and determine what units in each station would have to put on the line to deliver the desired volume at the line's terminal. Each station of this type is equipped with single stage as well as multi-stage pumps.

The practice of driving centrifugal pumps with slow speed Diesels was instituted during the past year. The high speed pumps are driven through gear increasers. This method

was developed by the Phillips Pipe Line Company on its gasoline line. Stations on that line were powered by gas engines, the fuel, liquid butane, being slugged through the line and stored at the stations in tanks and reduced to gas as needed. This company used one engine to drive each pump, the pump and gear increaser being mounted on the same foundation block.

Later The Texas Pipe Line Company adopted this practice on one of its Texas lines. When the Texas-Empire Pipe Line Company built its 50,000 barrels capacity line from East Texas to the Gulf Coast designers went further and drove two pumps with a single engine. Both pumps were driven through a gear increaser with a dual set of high speed gears. At one station an engine with a rating of about 1,500 h. p. was installed. The two pumps were connected in series and driven by the single engine through the gear increaser. Operation by this method has been satisfactory to date.

Another introduction to transporting companies was the light speed Diesel engine. The six cylinder unit develops 300 h. p. at 700 r. p. m. and weighs about 33 pounds per horsepower. Its first installation in the oil industry was at Mexia, Texas, on the Stanolind Pipe Line Co.'s system. It is used to drive a centrifugal pump through a gear increaser and the unit delivers about 25,000 barrels daily. The cost of this type of station is slightly less than $1.00 per barrel of capacity, on this installation.

Constant improvements are being made in the enclosed type of water cooling systems for Diesel engine installations. This system uses the oil going through the station as a cooling medium for the hot jacket water. Heat exchangers are installed on the suction side of the pump and the oil either passed through or around the tubes in the exchanger. In doing so its temperature is lowered and it travels on to the engine, to cool the jackets. It is forced through the water circulating piping by the water pump.

This method of cooling jacket water has virtually eliminated engine troubles caused by water difficult to treat. If the water at the station is bad it is treated before the system is filled. Thereafter only a small amount of make up water is required. Consequently scaling is diminished by always having good water going through the engines.

Temperature variation of the jacket water is controlled by the velocity of the water circulating through the system, either by regulation at the pump or with a by-pass. It is sometimes necessary to use a pump to offset the friction loss on the pump suction when the oil passes too slowly through the heat exchanger and does not permit proper filling of the pump.

It is these improvements in material, construction and operation along with scores of others that have made possible the wide expansion of pipe lines, transmitting gas to foreign and distant markets with large diameter lines. It has also opened the way for a more economic distribution of refined products by pumping them from refining centers to markets. Some students of the industry foresee the day when railroads will enter pipe line transportation to handle gasoline, utilizing their already purchased right-of-way and their communication systems.

Those vitally interested in natural gas transmission view a still greater expansion program and one that will bring gas to every industrial center. Eventually, the nation may be covered with a network of transmission lines permitting inter-connections of main lines. And as the transporting companies continue to improve methods it is not unreasonable to expect diminishing operating costs, permitting even wider expansion.

New type boring machine used on road and railroad crossings

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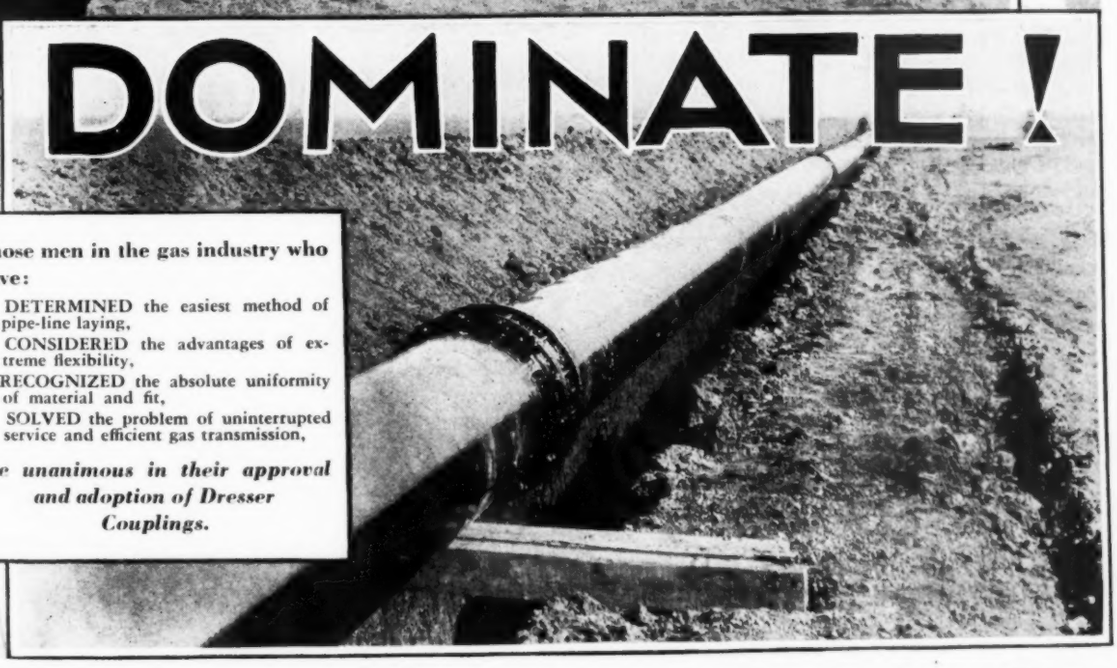

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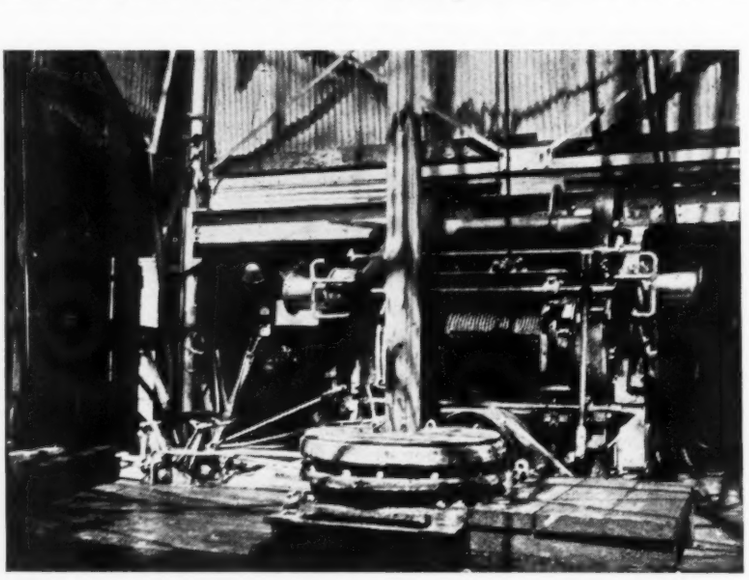
Equipment and Methods Improved

By WARREN L. BAKER

BETTER equipment and advanced methods now make possible many drilling operations that only recently were considered extremely difficult, or perhaps beyond probability of achievement. Improvements are continually being made, both in drilling practices and equipment, of vital importance in drilling to deeper zones, and in obtaining improved drill holes in both shallow and deep wells.

Three tests were drilled during the past year to depths exceeding 10,000 feet, the first time in history bore-holes have been carried so far into the earth. The deepest test in the world is the Penn Mex Fuel Company's No. 35, Jardin, near Alamo, Vera Cruz, Mexico, which attained a depth of 10,585 feet with an $8\frac{9}{16}$-inch diameter hole. This feat is all the more important because of obstacles encountered, not the least of which was a tremendous flow of salt water with a temperature of 160 degrees F., which enormously increased the difficulty of drilling. Only engineering skill and modern machinery made it possible to continue drilling successfully despite these hazards and handicaps.



Hydraulic Rotary Rig Powered by Vertical Steam Engine

Greater drilling depths have imposed greater loads on equipment, and necessitated the development of heavier machinery, stronger derricks, and more powerful prime movers. Realization of the advantages of drilling vertical holes has brought about radical changes in drilling technique, and has encouraged the development of much new equipment. Overcoming mechanical problems in deep drilling, means of drilling straighter holes, and the constant effort to drill more economically, stand out as the principal motives behind recent advancements in both practices and equipment.

Straight Hole Drilling

It is only within the last six years that serious attention has been given to the straightness of the hole drilled. Before that it was generally assumed that all wells were vertical. However, peculiar results frequently found as depths increased, indicated that some holes were not straight; and with the arrival of bore-hole surveying instruments data was evolved that substantiated this belief.

The vast number of complications and difficulties a crooked hole—particularly a deep one—can cause, may easily be appreciated, and serves to emphasize the importance of this subject.

Among many causes contributing to the deviation of holes from vertical, probably the most important is too much weight on the bit. One result of carrying too much weight on the bit is the flexing of the drill pipe just above the bit. The use of longer drill collars has been a help in this connection. As the string of drill pipe increases in length it becomes more flexible, and increases the tendency of the drill to deviate from the vertical, particularly if too much weight is carried on the bit.

When operators first began to check the deviation of holes from vertical, they changed their drilling practice. Limitations of bit pressures or weights on bottom were set, and frequent determinations were made of the verticality of the hole while drilling. This practice brought about the invention of many devices to aid in keeping holes straight and to determine the inclination of the hole from the vertical.

Automatic drilling control equipment, or means of controlling the feed of the bit, is one of the most interesting recent developments in drilling practice. The recognized advantages of straight-hole drilling have been instrumental in extending the use of these devices. They have been of decided assistance in regulating the weight on the bit, as have weight indicators, which have been used extensively in recent years on all deep wells. These controls may be set to maintain a predetermined tension on the drilling line and relieve the driller of much tedious work in manual feeding.

When the practice of limiting the weight carried on drilling bits was first started, there immediately arose the problem of lower drilling speeds and consequently higher drilling costs. Engineers studying the problem have developed indicating and recording pressure gauges, techometers, and other equipment for making observations of the various factors in definite terms of pressures, footage rates, or revolutions, as the case may be. The indicators are placed in a convenient position near the driller for frequent reference, while the recording instruments form a record for those supervising the work.

The general result of these close observations has been to increase rotary table speeds, with the result that the method of controlling the weight on bottom, as previously practiced, has given way to a combined regulation of table speeds and steam engine manifold pressures, as well as to limitation of the bit weight, and has resulted in better drilling time and more nearly vertical holes.

Higher speeds of rotation are being given serious thought by engineers, so as to profit by recent metallurgical discoveries in the manufacture of hard cutting alloys. However, further increases in rotational speeds involve a consideration of mechanical limitations, such as the whipping of drill pipe, proper cooling and flushing of the bit.

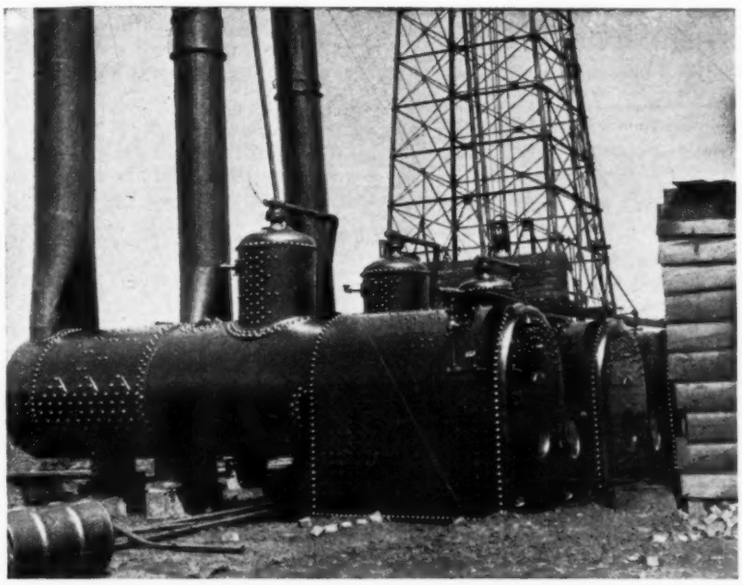
With Deeper Drilling Problems

L. BAKER

Metallurgy and Correlation of Equipment

Important advancements in improving the grade of equipment materials have been made by metallurgists, enabling manufacturers to use steel alloys and other exceptionally hard metals so as to increase the strength of equipment without increasing its weight. To date, the introduction of special steels and full-heat treatment have provided a satisfactory solution of the problem of increasing tensile strength and resistance to wear. Many special alloys, each with a particular field of application, have been introduced in the past two years.

It would be both a difficult and almost endless task to list the various and sundry applications of hard-facing and other special steels used in oil field drilling equipment, as in practically every piece of such equipment special steels or alloys comprise some part of its mechanism.



Installation of 125-horsepower, 350-pounds Working Pressure, Steam Boilers

A notable improvement in drilling bits has been the application of hard-set and hard-facing materials to the cutting and reaming edges. Drilling bits have been greatly improved in cutting efficiency and are one of the prime factors contributing to better drilling speeds. Likewise, many advancements in other parts of the rotary drilling machine are due to metallurgical progress in increasing the tensile strength and resistance to wear of steel and its alloys.

Correlation of drilling equipment has become an important matter to oil operators because of the need for obtaining a proper balance of strength between the different parts of the rig. Deeper drilling has imposed increased loads on all parts of rig equipment to a point where their proper selection in relation to the total load carried cannot be ignored. The practice of drilling contractors is to have every piece of machinery on a deep well of sufficient capacity and endurance to withstand, with a reasonable factor of safety, the maximum loads to be imposed upon it. The adoption of this policy has eliminated much shutdown time, which, otherwise, might have occurred because of some weak part of the equipment.

Along with correlation of drilling equipment has come the practice of using interchangeable units, so that drilling may not be interrupted while repairing a slush pump or engine. An interesting example of interchangeability of equipment through changing the usual rig set-up, is that in a well of the Cia De Petroleo Mercedes, in Mexico. The rig power, consisting of two 200-horsepower Diesel engines, is connected by a gear box and clutch in such a manner that either engine may be used to operate the rotary table or slush pumps, or one engine may perform both duties simultaneously. In this manner either of the engines may be repaired while the other operates the rig, thus eliminating shutdown time for engine repairs.

Drilling Fluid

Realization that the properties of drilling mud influence deep rotary drilling operations in a very important way, has led to much study and experimentation that has resulted in improved technique in the praparation, handling and use of drilling muds. Closer attention is now paid to the characteristics of the materials used, and more frequent inspections made to check the properties of the drilling fluid after it is placed in service. Drillers usually determine the density of the drilling mud by weighing it, but automatic devices are now available that indicate continuously — and record if desired—the density of the mud.

In some of the deeper fields, where high pressures are encountered, the character of the drilling mud is of paramount importance. Operators have been able to control excessive pressures by adding quantities of heavy commercial minerals, which condition the mud to give it the proper viscosity and weight. Drilling fluid weighing as much as 135 pounds per cubic foot that can be pumped, can be prepared by the addition of these commercial minerals, increasing as much as 80 per cent the density of ordinary clay-laden fluids, yet leaving the mud plastic enough to carry cuttings and seal the walls of the hole.

The practice in mixing commercial substances or clays to the mud already in the slush pits, is to add small quantities daily or every few days. It is mixed so that every particle is thoroughly wetted, and the resulting mixture free of lumps. The means adopted for mixing include the use of one of several mixing devices, which provide for the mixing of the proper quantities. Preparatory to adding the new mixture, the mud in the slush pond is first thinned out with water so that sand and foreigr materials will settle out.

A device for keeping mud in first class condition, and one which has become rather widely adopted by operators, is the vibrating screen. This screen is vibrated by mechanical means and is set up in the fluid system at the well so the return stream from the well carrying the cuttings flows over the screen. All the coarse gritty particles are screened out of the system and only the thin desired mud passes through the

screen. Besides removing the cuttings from the mud, the screen also aids in releasing any gas in suspension.

Considerable attention has been devoted in the past two years to field methods for the continuous reclamation and reconditioning of drilling mud. Heretofore, when muds became sand-laden or contaminated they were considered "worn out" and discarded. There are now several devices to aid in reclaiming mud, including the vibrating screen, and other more elaborate equipment. Some operators dilute the fluid, after which classifiers separate the sand from the mud. Later it is passed through thickeners where the excess water and other substances are removed. Several installations of centrifugal separators have also been made for reclamation purposes, and also chemicals have been used by a few operators.

Casing and Drill Pipe Problems

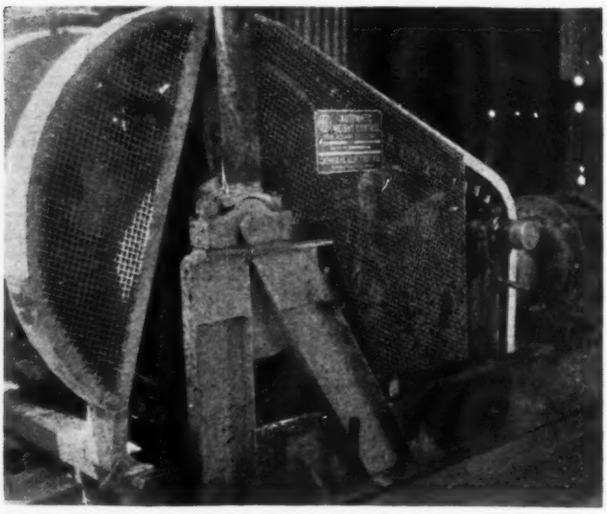
Deep drilling, the requirement of a reasonably sized oil string in the completed well, and the tremendous stresses to which pipe is subjected in deep holes, have created a demand for casing and drill pipe of materials with higher physical properties, so that tests may be carried to greater depths without reducing the hole diameter. There are now grade "D" tubular goods, having a minimum ultimate tensile strength of 95,000 pounds.

A record for long strings was established the past year with this new grade casing, when 9,777 feet of 6⅝-inch pipe was run in the Mid-Kansas Oil & Gas Company and Ramsey Petroleum Corporation's well at Cement, Okla. This casing string, consisted of 325 joints of 26.20 pound pipe, the upper part of which was coupled with nine-inch long thread couplings. The practice of using long couplings and longer threads on pipe is increasing, as it gives a slightly stronger joint than the shorter coupling.

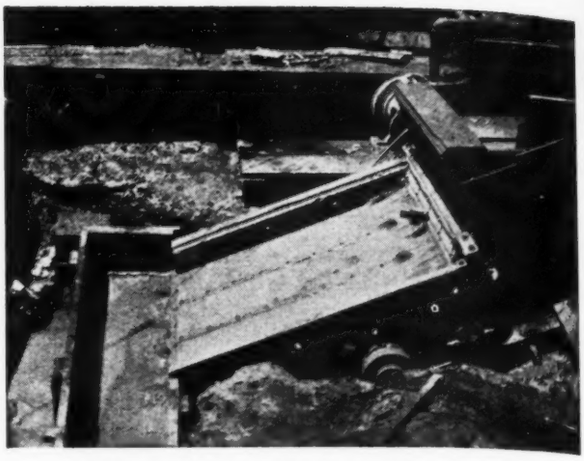
The greatest lessons learned from setting casing in deep wells have been the advantages to be gained by having ample clearance between pipe strings for circulation, and a good-sized diameter hole as deep as possible.

Engineers are devoting much time to the study of ways and means of obtaining greater clearance between pipe strings, and still maintain a hole of large diameter for deeper drilling. There is a growing use of flush joints, as they require less annular clearance space between strings or the walls of the hole. This type of joint has been used more frequently for drill pipe than casing, and its success in this use presages its wider use in the future casing programs of deep wells.

Future casing practice likely to be adopted for deep wells may be a combination of several methods, including the use of a larger size surface hole, longer casing strings, employment of under-reamers and flush-joint drill pipe and casing.



Automatic weight control instrument in use on an electric-powered rig



A Vibrating Screen Used to Improve Drilling Mud

When a long string of casing is run, it has become universal practice to "float" it into the hole. This method consists of placing float valves and float plugs in the bottom joint of pipe and filling the pipe with mud as additional joints are added. This procedure gives the pipe string buoyancy; thereby greatly reducing the dead load. It also is an effective safeguard against serious damage in case the string is accidentally dropped while being run in the hole.

Cementing Operations

Success in cementing deep strings of pipe has been due largely to the development of cement of greater strength and uniformity, and to advanced practice in the closer control of the water-cement ratio of the cement slurry. Also, cementing technique has been improved to meet the special requirements resulting from deeper drilling and abnormal subsurface conditions.

For some years the practice has been to circulate mud prior to cementing, with the object of clearing the hole of cavings and sealing up the walls. This operation has been improved by the use of lighter mud in "floating" casing into the hole, and by then using heavier mud to displace the cement after it has been placed in the pipe string. The use of light weight mud preceding, and the heavy fluid following, the cement reduces the pump pressure necessary and aids in rapidly placing the cement.

In some fields high temperatures have been encountered, which fact has led to the development of cements of special composition and grinding that set under high temperature; have a slower initial set, and thus allow more time for the cement to be placed before it hardens. In some areas where high temperatures have been found from 20 to 40 tone of ice have been dumped into the slush ponds, cooling the mud to a temperature of about 40 degrees F. This cooled mud is circulated in the hole, reducing the temperature at the bottom, thereby retarding the setting of the cement and offsetting the acceleration caused by excessive heat.

Increased depths and higher bottom-hole temperatures have speeded up all cementing operations, so that the time required to place cement behind a deep casing string will not be sufficient to allow it to harden. This has been accomplished largely by bigger equipment and mechanical arrangement and hook-up. In one instance, a string of 9⅝-inch casing was cemented at 5,500 feet in the record time of 34 minutes, including mixing and placing of the cement behind the pipe.

The latest development in oil well cementing practice is multiple-stage cementing, which process makes it possible,

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by means of one or more special casing devices, to pump cement behind a string of casing at two or more places. Consequently, the necessity of pumping cement all the way down the casing and then up the outside of the pipe is eliminated.

The process is expected to be especially adaptable to deep wells, as it will shorten the time required to place cement and therefore insure proper placing before it begins to set, and since the cement is not carried to the bottom of the hole it need not be exposed to the high bottom-hole temperature of deep wells.

Rig Construction

The 136-foot derrick, with a 26-foot base, has gradually come into popular use with deeper drilling, handling of longer strings of drill pipe, and the use of greater hoisting power and speeds. Simultaneously, steels of higher physical properties have been generally adopted for derrick construction. Derrick capacities have been increased by these high tensile steels approximately 50 per cent over previous ones without any material increase in weight. The heaviest type of derricks now have an A.P.I. rating of 1,000,000 pounds dead-load capacity.

The use, by many operators, of 136-foot derrick in preference to the earlier 122-foot derrick was practically forced upon them by larger traveling blocks, hooks and elevators, which reduced the margin of hoisting clearance between the blocks and the water table. This decreased the aggregate hoisting rate, since it became necessary for the driller to decrease the speed of the blocks at a corresponding lower position in their upward travel. Another advantage of the 136-foot derrick is the larger base, permitting a greater working area at the fourble board, which gives more room for free passing of the blocks at this point, while the larger floor space is desirable in more conveniently accommodating larger drilling equipment and additional drill pipe stands.

Some derricks of heights as great as 175 feet, and having a 32-foot base, have been used. These high derricks permit removal of six joints of pipe to the stand, whereas the 122-foot and 136-foot derricks allow only four joints to the stand, consequently they offer some advantage in deep drilling through decreased hoisting time.

Many operators consider improved rig foundation designs to be essential for use with the high derricks and on account of the greater loads imposed by deeper drilling. Larger and deeper cellars permitting ample working space around the heavier casing flanges and well connections are often an integral part of the improved foundations. There is also a trend toward the substitution of steel for the wooden under-pinning that supports the derrick floor and rotary table, and toward the use of thick concrete mats, providing greater bearing surface for the derrick and machinery foundations. Many companies now concrete cover all cellars, which makes neater and more fire-proof structures than the old timber ones.

An outstanding example of the importance of having ample cellar room is to be found in the Penn Mex Fuel Company's world's deepest test. The cellar at this well has an over-all clearance of 36 feet in depth, and nine feet below the derrick floor an L-beam was installed, on which was placed a special spider or special rotary table to aid in holding the weight of the drill pipe while coming in and out of the hole. The remainder of the cellar was used for large fittings and connections to control the salt water output. Without such a large cellar it is doubtful if this well would have reached a new world's record for deep drilling in face of the enormous obstacles offered by the hot salt water.

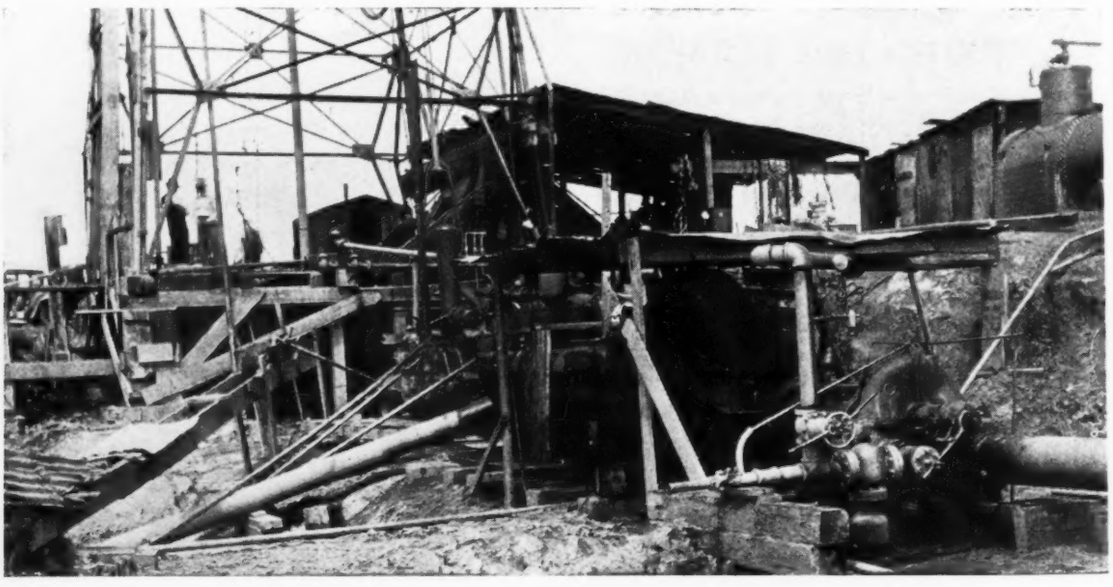
Steam Power and Steam Equipment

A majority of drilling rigs are steam operated. Recent trends in the use of steam for drilling operations have been toward increased power and efficiency.

The use of larger boilers with higher steam pressure capacities has been a general trend, especially in the Mid-Continent fields. Locomotive type boilers of 125-horsepower rating for pressures as high as 350 pounds per square inch have been universally accepted in the Mid-Continent for deep drilling. Many operators use super-heaters, insulate boilers and steam lines, and even house field boiler plants, to obtain better steam efficiency. Many types of super-heaters, either integral with the boilers or separately fired, are used.

Advancements in steam facilities and equipment have been toward greater power and efficiency, brought about more by a demand for greater power to meet conditions imposed by drilling to greater depths than by an economic demand for higher efficiencies. However, the effect has been two-fold.

Greater power, for deep drilling, in both pumps and engines, has been obtained by increasing the cylinder sizes, and utilizing higher pressure steam. Pump cylinders 18 inches



A View of the Steam Turbine-driven Slush Pump at Perry, Oklahoma

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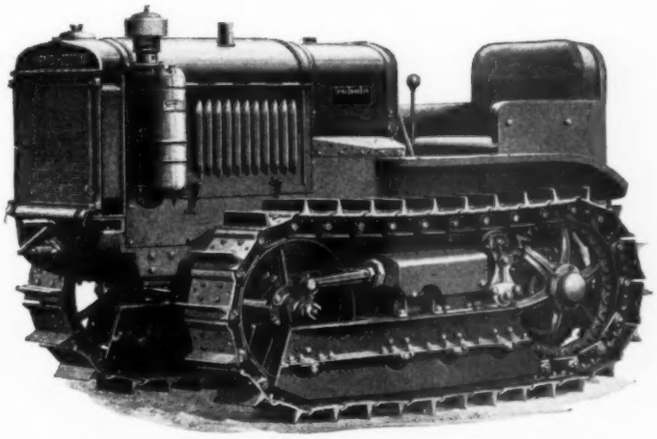

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in diameter, constructed for 350 pounds per square inch steam pressure, are in general use.

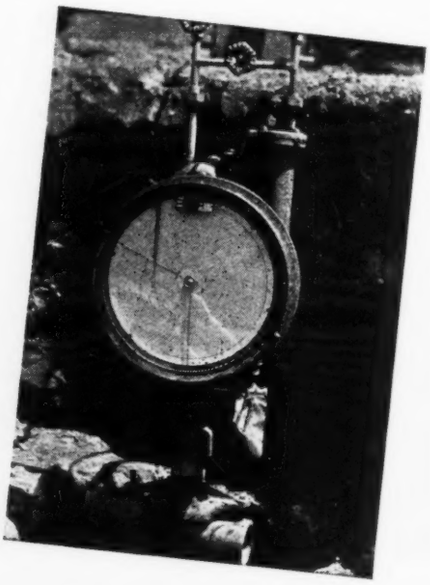
A radical departure from earlier designs in drilling equipment is the adoption of three-cylinder, 10 x 10, vertical steam engines for prime movers in some districts. This equipment uses a geared transmission type draw works, and a hydraulic rotary machine. The rotary machine is of special interest in that the drilling string may be supported by the table, which in turn may be elevated by hydraulic jacks. The jacks are an integral part of the machine, and the weight applied at the bottom of the hole may be controlled thereby.

Another radical departure in steam power application to rotary drilling was the use of a steam-turbine driven, 7 x 20 inch, duplex, power slush pump by the Magnolia Petroleum Company on a test near Perry, Okla. The results of tests conducted on the unit showed it to be quite satisfactory.

Other Type Prime Movers

There has been an increase in the application of electrical motors and internal combustion engines for prime movers in the past few years. Both the gas or gasoline and Diesel engine has been used in the internal combustion type class, and with considerable success.

As a result of deeper drilling, there has been a trend toward the use of motors with increased power ratings, until the 250-horsepower motor for hoisting purposes is not uncommon today. The need for increased flexibility in the application of alternating current electrical energy has brought about dual power ratings, specially designed mud-pump motors and improved control equipment. The dual powered alternating current induction motors are generally of 250- and 85-horsepower rating, the higher power rating being used for hoisting operations and the lower for drilling purposes. Control equipment for electric rigs is being rapidly changed to the magnetic control type apparatus.



Left: A hydraulic mud pump pressure gauge
Right: Steam recording gauge on steam line to slush pump

The use of direct current electrical power has been an important development in the application of electrical power to drilling. It has flexibility, a desirable feature for drilling operations. The direct current power is generated at the rig by gas, gasoline or Diesel engines driving direct current generators.

Diesel and gas engines have been greatly improved within the past 12 months and will probably be more common for drilling purposes in future years. Considerable interest has been devoted to these internal combusion type prime movers by operators in the past two years.

General Rotary Equipment Advancements

There has been no marked change in the basic design of chain-driven draw works, swivels, hooks, traveling and crown blocks, and rotary tables, but there has been marked increase in size of these parts, which, with the improved grade of materials, general adoption of roller bearings and full oil-bath features, has resulted in the construction of greatly improved equipment.

Improvements in draw works have included an increase from three to four speeds, increase of the line and drum-shaft diameters to as great as 9½ inches, use of cast steel or alloy and manganese cast steel sprockets, roller bearings, steel posts and larger brake drums. Practically all drums are equipped with roller or forged steel brake rims, which are, in many cases, provided with water or air cooling features. The latest draw works are effectively equipped with guards, eliminating many of the hazards to workmen that previously existed on the rig floor.

The present practice in hoisting heavy strings of drill pipe or casing of using ten lines in the derrick has necessarily retarded pulling speeds. With the crew working as fast as careful handling would permit it required approximately seven hours to bring 10,000 feet of 4½-inch drill pipe to the surface and place it back on bottom at the Mid-Kansas and Ramsey well. Round trips with 7,500 feet of drill pipe have been made in four hours where the 136-foot or greater height derrick was in use, due to the ability to pull one or more joints of pipe each trip.

Rotary swivels of recent design are capable of satisfactorily handling twice the load, and at double the rotational speed, of earlier designs. Rotary hose has been materially strengthened to handle this greater friction and shock load.

The outstanding change in traveling block and crown block design has been the double-deck feature, in order to permit the use of sheaves of greater diameter without increasing the size of the derrick water table opening. It has been found, from an intensive study of wire rope service, that important advantages are obtained by the use of larger diameter sheaves. Another feature of block design has been the increase in number of sheaves so as to accommodate an increase in the number of lines used on deep wells.

Future Improvements

As wells are drilled deeper and deeper and equipment is more improved, further progress in drilling practice will depend upon research, and also upon drilling methods and technique that have been and are being given considerable study and thought.

Future improvements in drilling machinery will likely be more along metallurgical lines and changes in design, rather than enlargements, because the limits of portability will soon be reached at the present rate of increasing weights.

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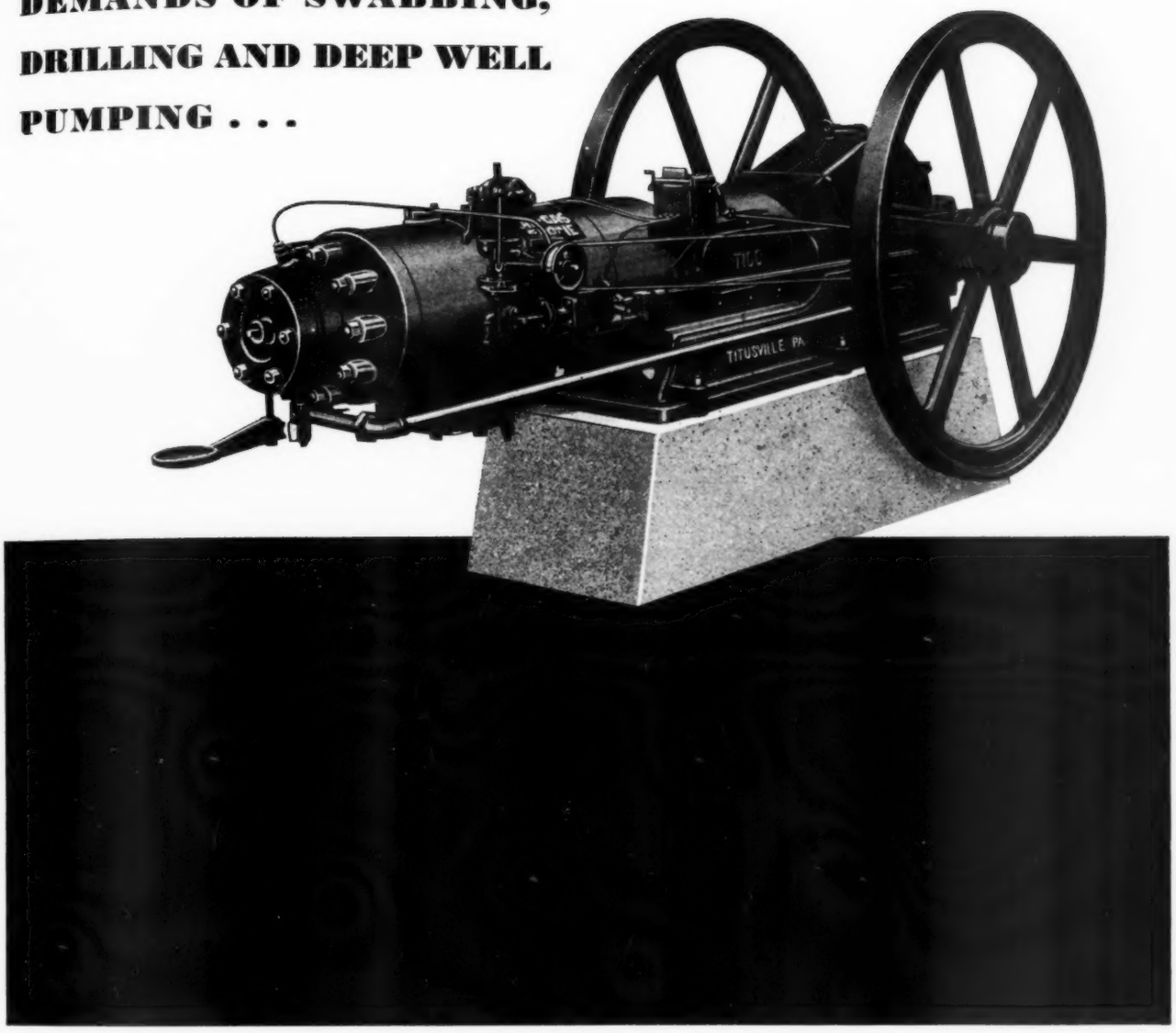

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Recent Trends in Western Pennsylvania Refining

By GEO. M. KIRKWOOD,
Assistant Superintendent, Pennsylvania Refining Co.

THERE are a number of methods used in refining Pennsylvania grade crude oil. They are, however, all alike in the respect that the production of lubricants, or special products, such as white and medicinal oils or petrolatums, is their main objective. The other products such as gasoline, naphtha, kerosene, gas oil, and wax must of necessity be made and disposed of at the best possible advantage. These products, with the exception of gasoline, are of the highest quality, and are marketed with little difficulty. The gasoline, however, is a different matter, its low octane number, in these times of high compression motors, makes its disposal more difficult.

There are five courses open for Pennsylvania refiners in marketing their gasoline. First, it may be sold as straight run motor gasoline after adjusting its volatility with natural gasoline. Second, it may be fractionated into special naphthas, such as rubber solvents, cleaners naphtha, mineral spirits, etc. Third, it may be blended with benzol or other knock suppressing hydrocarbons and sold as anti-knock gasoline. Fourth, it may be blended with Ethyl fluid and sold as Ethyl Gasoline. Fifth, a cracking or reforming unit may be installed, which will produce a good anti-knock motor fuel.

Most Western Pennsylvania refiners, as mentioned before, are chiefly interested in manufacturing lubricants, and would like to dispose of their gasoline as a straight run product, but such a course is becoming more and more difficult. In this connection, there is some indication that mechanical changes in gasoline motors, such as improvements in fuel injection, and aluminum alloy cylinder heads, may lead to the satisfactory use of gasoline of low octane number in high compression motors. One group of Pennsylvania refiners has solved its gasoline problem by means of a co-operative cracking plant. A few have installed individual cracking or reforming plants, and the others are marketing their gasoline in one or more of the other four methods as outlined above.

Distilling equipment is divided into three general types. There are batch stills, continuous batteries of batch stills with fractionating towers, and tube stills with fractionating towers. Some of the latter top the crude under atmospheric units. Excellent lubricants are made in all of this equipment, but the tendency is toward installing tube still units which give much better fractionation, require less space, and are more efficient from a standpoint of fuel economy and operating expense.

The procedure in making lubricating oils varies rather widely. Some refiners run to long residuum, 80 to 90 viscosity at 210 degrees Fahrenheit, and others to 140 to 150 viscosity cylinder stock. Some dewax by cold settling, and others by centrifuging. Some refiners finish their neutrals and bright stocks separately and blend into the different motor oils, others mix their pressed distillate and centrifuge solution and reduce to motor oil specifications, taking off some light lubricants overhead. The most general practice is to run to 600 S. R. stock, which is partially filtered in solution, and dewaxed. The diluent is boiled off either in batch or tube stills, and the bright stock filtered to the desired color. A common procedure is to dilute the stock with 50 per cent of a close cut, high gravity, naphtha filter to about 7 N.P.A. color in solution, transfer to a mixing tank and dilute further (about 65 per cent naphtha), heat to about 90 degrees Fahrenheit to assure complete solution, transfer to insulated chilling tanks where it is cooled to about 40 degrees fahrenheit below the desired cold test, and centifuge. The filter wash from the solution filters is used as the diluent for the next batch to be filtered.

A few refiners make finished petroleums from the amorphous wax, filtering to the various commercial grades, snow white, lily white, cream white, extra amber, amber and red veterinary. The refiners not making finished petrolatums, either sell their amorphous wax to those who do so or mix it with fuel oil and burn it. In some cases it is used as charging stock for cracking stills.

The wax distillate is cooled by brine in chilling machines, and filter pressed. The pressed distillate is rerun in either batch or tube stills and separated into fuel oil, non-viscous, and viscous neutrals. The press (or slack) wax is sweated to the desired melting point. Usually two cuts are made, foots oil, which goes back into the wax distillate to be filter pressed, and second cut, or intermediate, which is mixed with the press wax. These cuts are determined by the melting points of the stream coming from the sweat pans. The sweated wax is filtered through fullers earth and either chipped and packed in barrels or molded into cakes.

Filteration is accomplished mostly in percolating filters, there being only two contact plants (to the writer's knowledge), in the Western Pennsylvania field. Clay burners are the Nicholls-Hereshoff, rotary kiln, or Ritchie type. A program of co-operative research on filteration has been started by a number of Pennsylvania refiners which may result in some changes in practice within the next year or two. All phases of filteration are to be covered in this work, including a comparison between contacting and percolating, and considerable improvement over existing methods is looked for. At the present time nearly every refiner has his pet theories regarding the relative merits of such factors as direction of flow, filter size, soaking time, pressure, etc., and scarcely any two filter plants are alike.

Pennsylvania refineries are, generally speaking, small units. They refine the highest grade crude oil for making lubricants. They have no serious corrosion problems. The distillates require but a light treatment to sweeten. These factors have in the past made Pennsylvania refiners somewhat backward in adopting new equipment and methods, and have retarded research. The changing of oil refining from a comparatively simple operation to a highly technical chemical industry is altering this condition rapidly. Business conditions have necessitated efficiency and economy heretofore unnecessary. Co-operative research, begun in a small way, may be expanded considerably in the near future. The progressive Pennsylvania refiner is keeping up with the changes in the industry.

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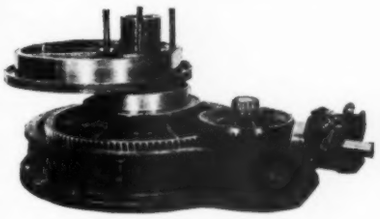

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Weight, with 30″ eccentrics	18,500 #
Weight, with 36″ eccentrics	20,000 #
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Application of the Internal Float Liquid Level Controller

By KENNETH R. D. WOLFE☆

THE automatic liquid level controller has played a prominent part in development of the many complex problems of the oil industry, from production to the service station. Basically, there are two classes of float level controls—the Internal Float, and the External or Float Cage type. These two classes can each be further divided into the direct operated type, where operating lever and stem of the float is connected directly through a turnbuckle rod to a lever valve; and the remote type, where a pilot valve, utilizing an auxiliary operating medium, is connected to the float stem and the auxiliary pressure passing through the pilot is connected to a diaphragm motor valve located remotely from the tower or liquid container on which the control is installed.

The internal float controller class is, by far, the older of the two, but for several years has been of secondary importance. Today, however, the foremost designing, consulting, and construction engineers are giving attention again to internal float controls.

The internal float class has many operating features, the most important of which is its suitability for opertaion on the bottom of towers, or in any liquid container handling very viscous fluids which must be kept under a high temperature in order to keep them in the liquid state. The internal float type, being connected directly to the side of the tower, does not permit any greater heat radiation than the wall of the tower itself, and in some installations the body of the control has been practically entirely insulated. Thus, it does not require any auxiliary heating to keep the liquid around the float at the proper temperature.

The internal float, operating directly inside of the tower and on the surface of the main volume of liquid, positively follows the true liquid level, more so than the external float. The external float equipment has an advantage, however, in this respect, because of its nature it is not subject to surges or waves that may be set up on the liquid surface. Sometimes, however, interior baffle plates are used in connection with the interior float and successfully overcome difficulties of this type.

The flexibility of the interior float control is extremely great. It is easy to include with various special designed

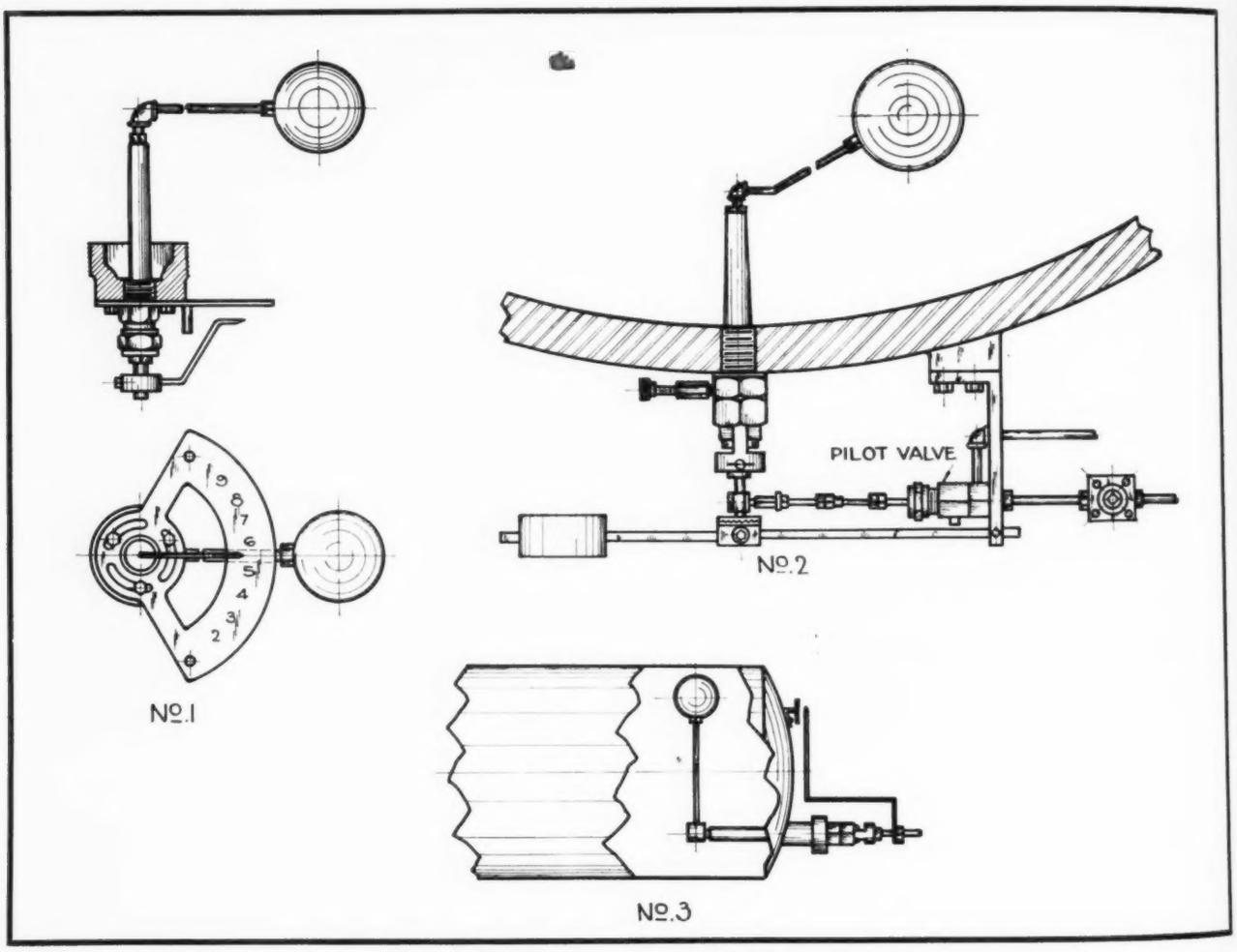

Fig. 1. Stuffing-box or screw type internal float controls

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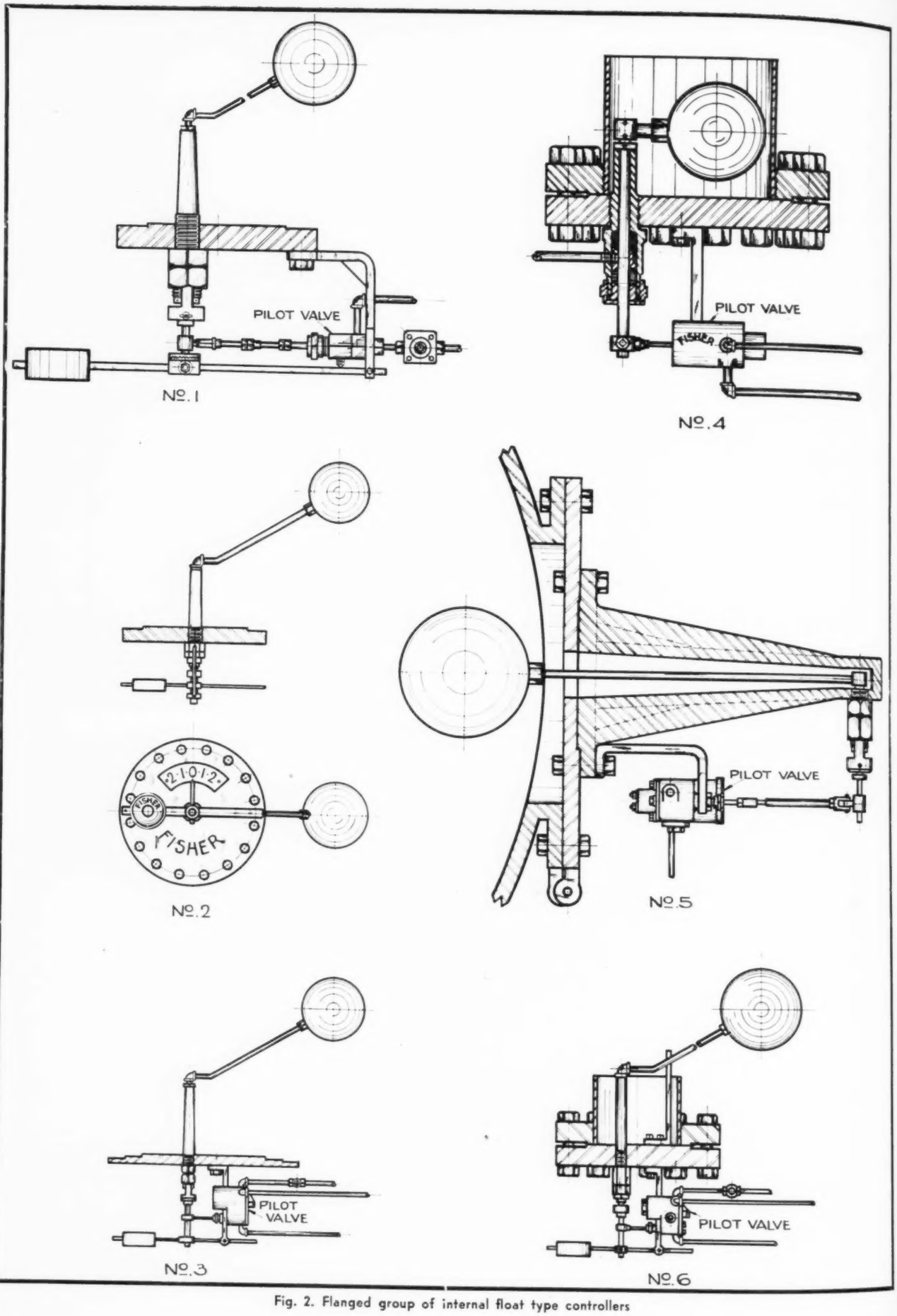


Fig. 2. Flanged group of internal float type controllers

towers, tanks, and liquid equipment, tending to create more compact installations and greater economy of initial cost. The variety of internal constructions illustrated in this article very well portrays the flexibility of the units and the possibilities for adaptation to different types of problems.

Unlimited float size, power, and travel, are important features. With this type of equipment, any size of float can be used, practically any length of float rod, and by slight variations in the construction, various lengths of float travel are obtainable. This tends to give greater power for operating a valve directly and for controlling special equipment which requires these features.

Usually, the internal float arrangement can be used with low initial cost. This is particularly true with the steel, high temperature installations, which are used for most refinery construction.

Due to the very nature of this class of equipment, it is impossible of course, to cover all types of problems and construction details which may be experienced by the engineer. For that reason we will discuss and illustrate equipment which has actually been used on various types of installations in refinery and oil field practice, and no doubt these will parallel many problems now existing.

Types of Internal Float Level Controllers

Up to this point we have made several divisions in liquid level controls and now it is necessary to divide the one main class which is under discussion—that is the internal float type. These are manufactured in really three different groups. The first group that we will discuss will be considered as the flanged group. Several of these are shown in Figure 2. Although there are six different units illustrated here, some of which may appear at first to be identical to the others, each of them has a distinct feature which meets particular problems in a better manner than some other type of control. In this group let us refer to number 1.

This unit is equipped with an external lubricated ball bearing stuffing box and is furnished with a steel blind plate flange and connected to this is a bracket, holding a pilot valve for the operation of a diaphragm motor valve through remote control. The stuffing box is especially designed with long threads and an extra long body. On some high temperature installations it is desirable to insulate over the blind flange after the unit is in place. The body of the stuffing box must, therefore, be long enough to protrude beyond the surface of the insulation in order that the packing gland may be open for regular inspection and lubrication.

This type of control is often used for controlling the liquid level in the bottom of vacuum towers, atmospheric towers, and surge pots.

Number 2 in this group shows a small flanged controller with a pointer indicator scale on the face of the blind flange. There is no need for discussion regarding this unit. It is, likewise, suitable for high temperature and pressure and on any gravity of liquid. It is a very desirable unit, where it is necessary for the operator to watch a given level through a device of this type.

Number 3 shows another variation of the remote or pilot operated type, but the distinction between this and the ones mentioned above is the fact that a boiler plate flange of large diameter is used. Most of these are approximately 24 inches in diameter, permitting their use on large man-holes and when the control is removed for inspection, it is possible actually to use this passage for the man-hole in cleaning the tower. This eliminates an extra attachment or connection for a separate liquid level control, and really utilizes the man-hole cover as the float stem support.

Number 4 shows a unit designed for a special operation where it was impossible to place the float inside of the tower. In this case, a nipple 10 inches in diameter and several inches long, was welded to the side of the tower and this flanged arrangement fitted to it with a small internal float. It is a high-temperature installation, working on vacuum. Note the lubricated stuffing box which also acts as a vacuum seal. Oil is circulated through the stuffing box. The outlet pipe, from the oil circulation of the stuffing box, is not shown as it is taken off the bottom of the stuffing box. This unit is also pilot operated.

Number 5 in this same group illustrates a rather new departure in the flanged type of control of the internal design, in that a regular float cage arm has been designed to fit a boiler plate flange which fits a regular man-way opening in the tower and a unique hinge has been developed and welded to the blind flange and the tank, permitting the swinging of the float mechanism away from the man-way when cleaning. This unit is a real labor-saver as one man can easily unbolt the flange and swing the unit clear of the man-way, preparatory to cleaning the tower. The unit also shows a pilot valve for remote operation.

Number 6 is a unit which has been widely used in many of the new plants and refineries constructed in the past year. Several of these were used in a refinery constructed in Houston, Texas, last year and in another at Augusta, Kansas. This unit is shown connected to a nozzle designed for welding to the tower and it is furnished with high pressure steel flanges and internal float stops. The stuffing box is of the vacuum seal lubricated type.

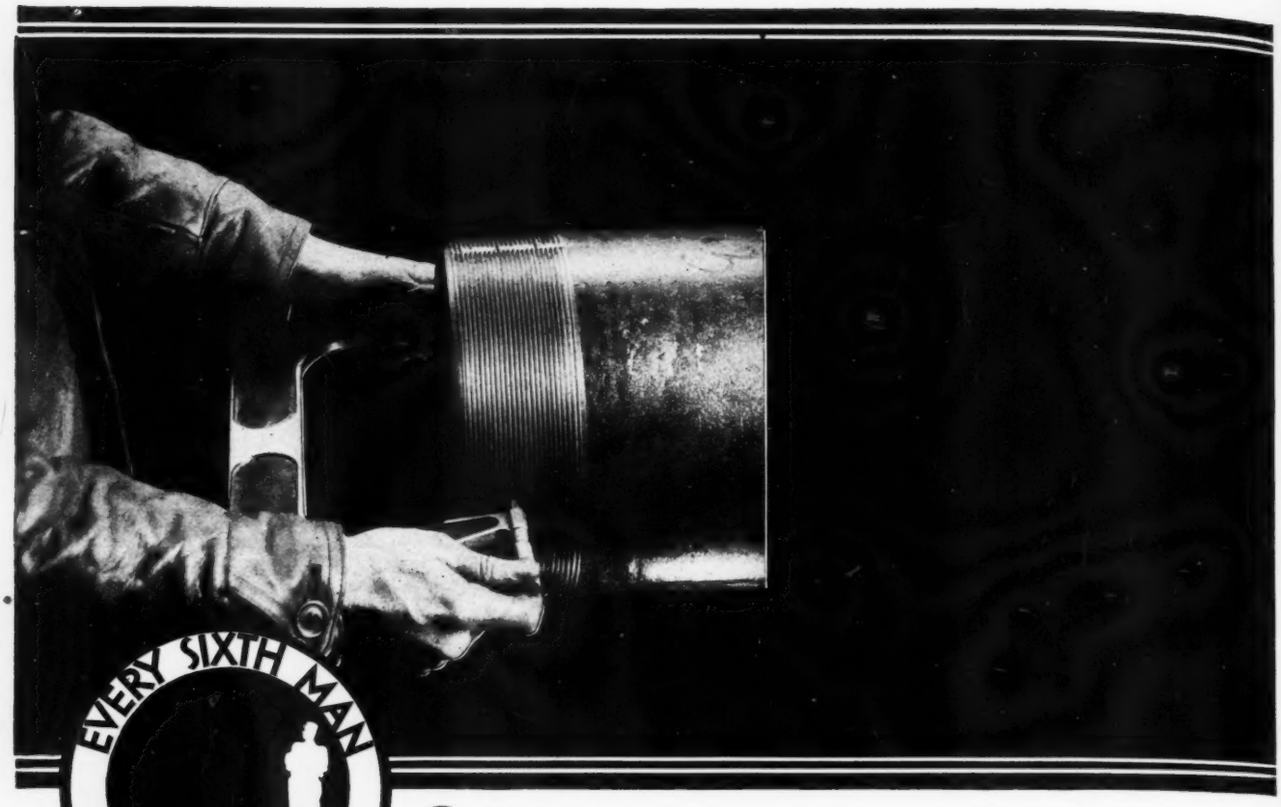
All of these units have been used on practically every gravity oil from the heaviest bottoms to the lightest naphthas. Various types of floats are obtainable today so that the old objection of float trouble is practically eliminated. A few years ago it was not uncommon to have to replace floats, due to slight corrosion, every month or six weeks. This was, however, before the time of stainless steel floats which have met with such exceptionally good success in corrosive refinery service. With this type of float it becomes unnecessary for a short time inspection period, as usually the units operate satisfactorily throughout the regular period of operation of the tower and then can be inspected at the time the entire equipment is checked over.

The writer is acquainted with installations where this type of control is being used with very good success on the following installations: level control bottom of naphtha strippers, level control bottom of kerosene strippers, level control bottom of gas oil stripper, level control of atmospheric towers, level control on surge pots, and for level control on the bottom of vacuum towers.

Another class of the internal float controls is the stuffing box or screwed type. Four of these varieties are shown in Figure 1, the Number 2 of which shows a unit installed directly on the side of a tower. With this type of equipment it is, of course, necessary either to weld two bosses on the tower or have such provisions made, when the tower is constructed. On this type of control it is necessary to put the float on the float rod after the stuffing box is in place. In other words, there must be a man-way large enough into the tower to permit the insertion and removal, and installation of the float from another point. This unit has a variation from any of the others shown in that it has a solidifying grease lubrication connection, and utilizes a separate bracket for holding the pilot valve.

External travel stops are used on the brackets to prevent the float from over- or under-travel.

Number 1 shows a small level indicator often used on the ends of horizontal tanks to replace gauge glasses. This is particularly well adapted for such installations where the use of a gauge glass may be a fire hazard. This nuit has the adjustable indicator scale and can be furnished with the float



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small enough to pass through the tapped opening for the screwed body.

Number 3 shows a still different type of the stuffing box variety of internal float controls. This is used primarily as a pointer indicator on the end of horizontal tanks. However, it is fastened to the tank itself by a flanged nozzle; a 3-inch inside diameter nozzle with the flange attached to it, is welded to the tank and acts as a support for the stuffing box chamber. This was designed primarily to keep the stuffing box gland as far away from the main tank and volume of liquid as possible due to the extremely high temperature inside the container. This unit has been operated on hot crude oil at temperatures 750 degrees and 150 pounds pressure with very good success, and through this unique handling, the stuffing box is not subject to undue temperature and consequently stands up very well.

Number 4 illustrates the unique adaptation of the internal float for operating electric contact and the elimination of additional bosses other than the one used for the insertion and threading in of the stuffing box itself. In this case, the stuffing box body forms the bracket support for the switch and the internal part of the stuffing box forms a travel stop.

This entire group of controls is recommended primarily for their savings in initial cost and for many of the minor level control problems experienced in a refinery, or gasoline plant. From the few illustrations that are given above, it can be readily understood that the flexibility of these units is extremely great, and makes special adaptations of them very easy.

The last group of the internal float controls is known as the cast flanged body. These are primarily designed for installation on towers where heavy insulation is used. With this design the main part of the body and the stuffing box protrudes well beyond the insulation.

Sometimes these units are equipped with a Mercoid switch having a double tube especially designed for remote indication. This unit works five lights which consequently indicate five different positions of the float. This is used extensively for this service and has been used on atmospheric treating towers, fractionating towers, handling 10 degrees A. P. I. flux, under temperature 750 degrees and also on high gravity naphtha. A recent installation for the Russian government utilized a similar control extensively.

A similar control of this group has special interior adjustable float travel stops and an exterior oil seal switch. This likewise is suitable for high pressures and temperatures but is designed primarily for operation on high gravity liquids.

A special high pressure arrangement for high temperature service and well illustrates some of the various adaptations which have been worked out on this class of equipment. This particular control was designed for a powerful float action. Consequently the long float rod, yet a small travel and close coupling of the pipe connections were desired. The pilot operation was utilized in connection with this. The pilot is illustrated, connected to the flanged unit, by a bracket.

These cast flanged internal float controls are frequently used as direct operated float units, sometimes varying in that they utilize the duo-gravity float feature which works on the inner face of two liquids having different gravities such as water and any lighter oil. The float is so balanced as to sink in the oil and float on the water, thus giving accurate separation of the two fluids. A special hollow stem arrangement is utilized for adding or removing lead shot for balancing the float.

The cast flanged is also used as a complete pilot together with the main valve. This is of the remote type and the valve can be installed in any line which is connected with the operation and maintenance of the level. These are used extensively for operating input or output pumps, the valve being installed in the steam line to the pump.

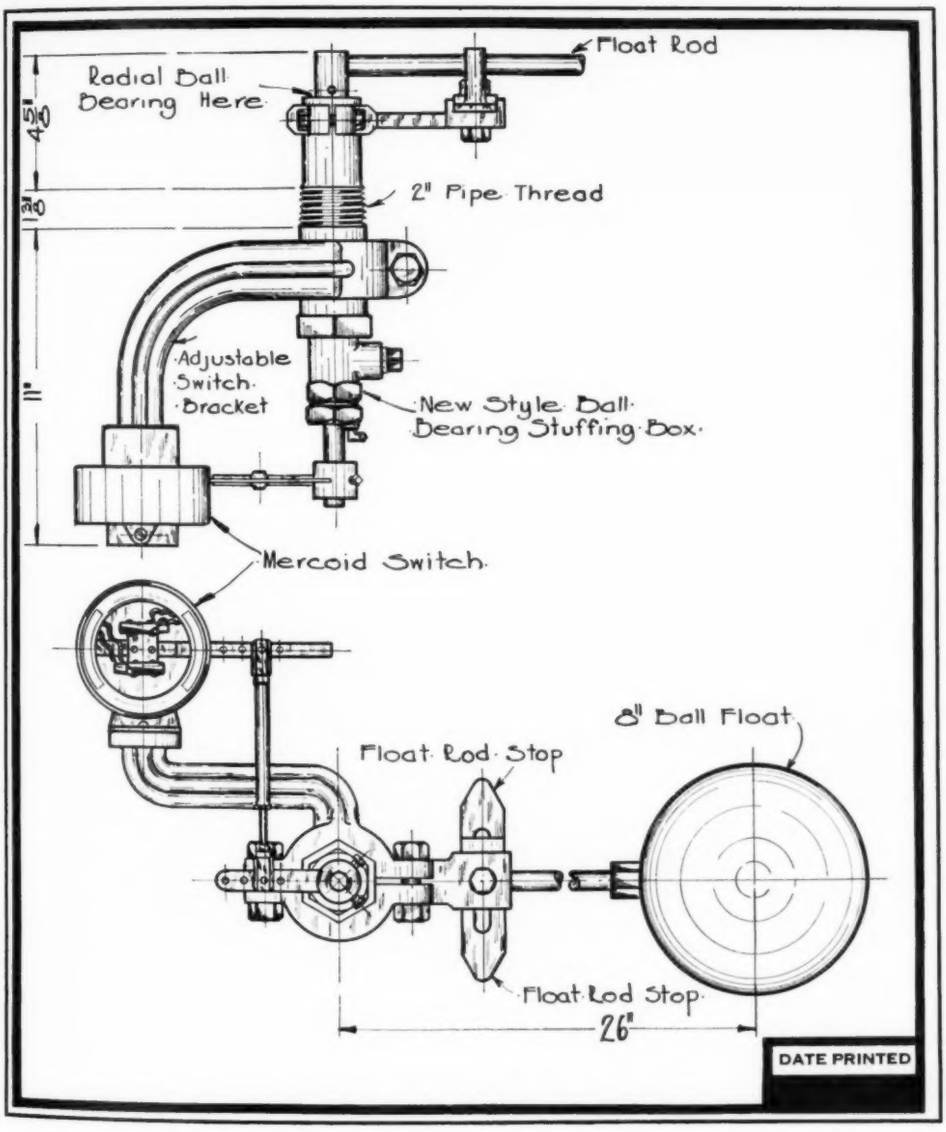


Fig. 1, No. 4, showing unique adaptation of an internal float operating electric contact

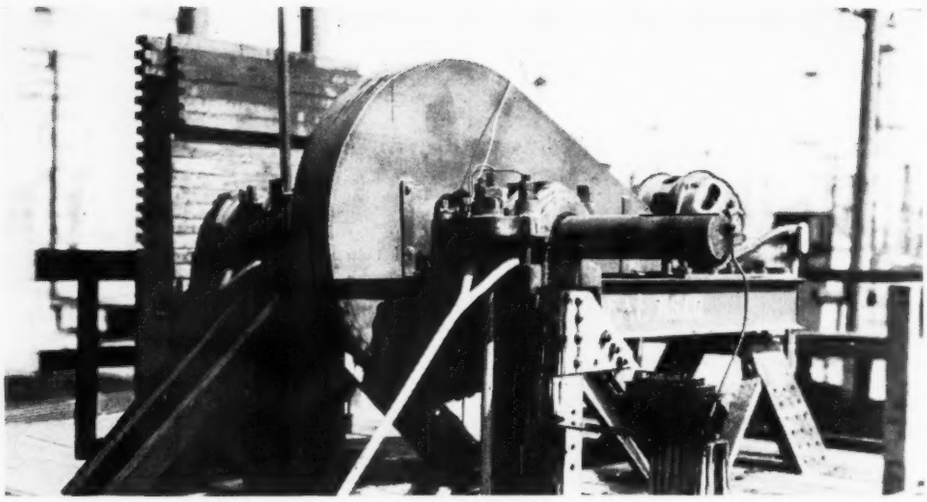


Figure 1.
A view of the
Crank-shaft Type
Pumping Unit.

Deep Well Pumping in California

By C. L. MOORE☆

THE problem of economically producing oil from wells 4,000 to 7,000 feet deep, after such wells have ceased to flow is of prime importance to operators in the comparatively recent deep zone fields of Southern California.

The technique of drilling deep wells has been developed and applied with remarkable success in recent years, and to undertake the drilling of a well to 7,000 feet or more is now a matter of ordinary routine. Such wells usually flow for a period of several months and they generally give little trouble during this period from a producing standpoint. The principal problem presented by such wells is the economic one of disposing of the oil without flooding the market.

When formation pressures have declined to where these deep wells will no longer flow steadily under their own pressure, it is common practice to prolong the flowing period by the use of gas lift. This additional period of artificial flow varies over wide limits from a few weeks to several months.

A great number of the deep wells in the Los Angeles basin fields have now passed through the period of natural and artificial flow, and other methods of producing these wells must be resorted to. During 1931 there were 1525 producing wells in the deep zone fields of Southern California, and their daily oil production varied from 49 barrels per well to 203 barrels per well, based on field averages. It is evident that wells of this size will not usually flow by straight gas lift. Many of them are being produced by some type of intermittent gas lift, which offers several advantages for wells of this type. However, an increasing number of these deep wells are being placed on the pump, and usually operated by the standard surface equipment.

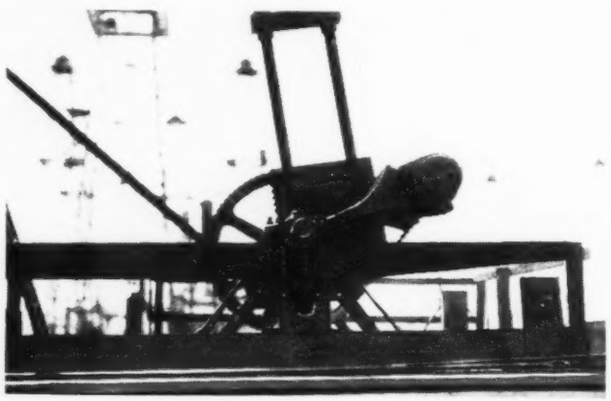


Figure 3. New Pumping Unit, which is suspended directly on crank-shaft

The technique of pumping these deep wells is being rapidly developed, and engineering data which have been gathered on this subject over the past four years are now proving their value, and have enabled operators to avoid what would otherwise have proven insurmountable mechanical difficulties in deep well pumping. An outstanding example of engineering research of this character was that presented by Mr. F. W. Lake before the American Petroleum Institute in 1928.[1]

The development of deep well pumping in California, together with a technical analysis of the problems involved is fully covered in a recent paper[2] presented before the American Petroleum Institute, and the present paper will only attempt to describe the latest methods and equipment that are being used.

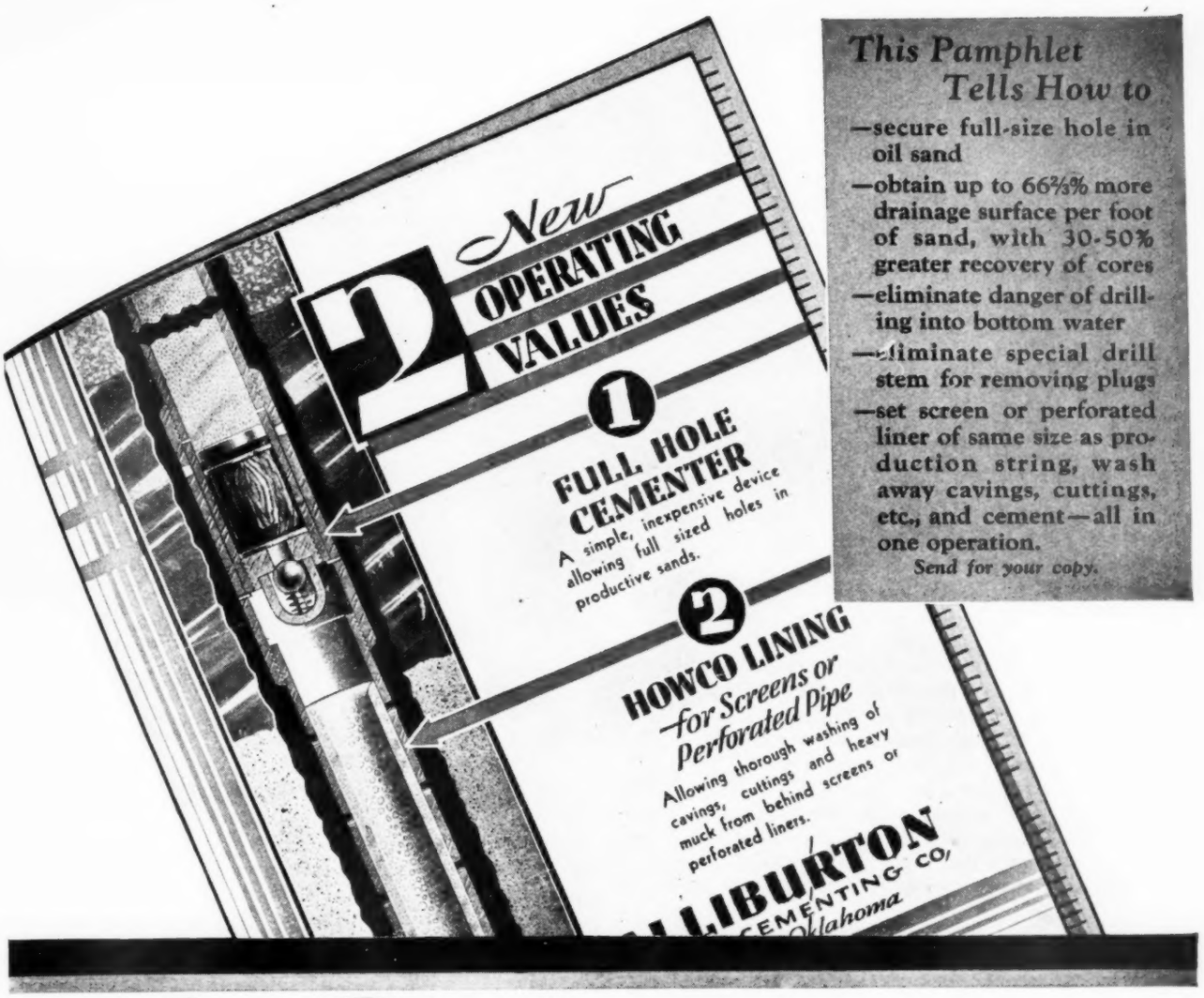
The entire problem of deep well pumping has been the question of securing sufficient plunger displacement in the pump to maintain the desired recovery rate, without excessive mechanical trouble with sub-surface equipment. However, as the recovery rates from these deep wells continue their inevitable decline, this problem gradually merges into the question of merely securing the correct plunger displacement to accommodate this lowered recovery rate in the most efficient manner. This problem is important, as the existence of these wells as competitive producing units, depends upon its solution. They are rapidly approaching the status of "marginal" wells, and due to the great depths from which the oil is lifted, the cost of production is likely to exceed its value at much higher recovery rates than is common with the shallower wells.

The increased recovery cost per barrel of oil pumped from deep wells as compared to shallow wells is shown in Plate 1.

[1]Lake, F. W., Union Oil Company of California, Los Angeles, Calif., *The Action of Deep Well Pumps*, A. P. I. Bulletin, Vol. X, No. 2, January 3, 1929, pp. 55-66.

[2]Robinson, B. H., General Petroleum Corporation, Los Angeles, Calif., *Deep Well Pumping in the Santa Fe Springs Field*, A. P. I. Bulletin 208, December, 1931, pp. 174-178.

☆ Engineer, Chanslor-Canfield-Midway Oil Company, Fellows, Calif.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It will be noted that the energy demand per barrel produced varies directly with the depth, and the dynamometer cards shown in this plate are from slow speed wells in which there is no dynamic load due to acceleration.

There are quite a number of small wells in California producing from depths of 3,000 to 3,500 feet, that are being successfully and economically operated by reducing the pumping speed to the critical minimum plunger displacement, which will secure the maximum recovery rate from the wells. This is the basic principle of slow-speed pumping, which is being applied on a large scale in the shallower fields of California. The dynamometer cards shown in Plate 1, are typical of these slow speed wells operated at the correct critical speed. As a rule these cards shows a remarkably close correlation with the calculated or theoretical card. These calculated cards are based on the computed weight of the fluid and rods, and the rod and tubing stretch. The formula used for computing the net plunger stroke is that given by Marsh,[3] which appears to give a close check on slow speed dynamometer cards when the well is operating at its correct critical speed.

C. L. MOORE

With a given set of conditions on an individual well it is possible to compute the plunger size, stroke length and pumping speed that will best fulfill such conditions, and these computations will usually check the actual operation of the well provided the required jumping speed is low enough to avoid much dynamic loading. The dynamic load does not exceed 7 per cent of the static load at eleven strokes per minute with a 24-inch stroke, and 7½ strokes per minute with a 54-inch stroke. If the required pumping speed on a given well exceeds these values, the problem of computing actual plunger displacement, becomes difficult and involved due to the elasticity of the rod string.

In Plate 2 is shown the analysis for an assumed set of data where it is desired to secure the best operating conditions for 50-barrels-a-day plunger displacement at a maximum pumping speed of 7½ strokes per minute with a 54-inch stroke. The pump depth is assumed at 6,000 feet and the well is equipped with 2½-inch tubing and ¾-inch rods. The simplest and most economical change in equipment is varying the plunger diameter. A calculated set of dynamometer cards could be computed as shown in Chart 1, or the displacement with plungers of different available diameters may be computed directly and plotted as shown in Chart 11. This analysis indicates in this well that a maximum plunger displacement of 50 barrels per day may be secured with a 1½-inch plunger, at the maximum pumping speed of 7½ strokes per minute and 54-inch strokes.

Various types of insert pumps with plungers from one inch to 1¾ inches in diameter are now readily available and are proving their worth in deep well pumping. As shown in Chart 11 of Plate 2, a one-inch plunger would provide five times the plunger displacement of a two-inch plunger, with the well operating at the same speed and stroke length. This general condition is well recognized by California operators, and the most significant trend in deep well pumping during the past year has been the ever-increasing use of these insert pumps with small plungers.

Surface Equipment

There has been witnessed during the past year in California a remarkable development in surface pumping equipment for the operation of small wells at comparatively shallow depths and pumping speeds of from one to six strokes per minute. This development has been responsible for the generation of new ideas in pumping equipment design, and some of these new ideas are now being incorporated into the design of heavier equipment for operating deeper wells at normal pumping speeds of 25 strokes per minute or more. Two very interesting ideas that have been developed in this manner are incorporated into the design of a so-called "bandwheel shaft" or crankshaft pumping unit, shown in Figure 1 and Figure 2. One end of this unit is supported on the crankshaft, the bandwheel having been removed. A bearing sleeve and large sprocket are keyed to the crankshaft, and this end of the pumping unit is supported by means of a floating housing on the bearing sleeve. The rear end of the pumping unit is supported by a torque post, and the suspension of the unit on this post is of particular interest. By referring to Figure 2 it will be noted that the frame at the rear end of this unit is supported between two heavy springs. Only the base of the lower spring can be seen

[3]Marsh, Hallan N., General Petroleum Corporation, Los Angeles, Calif., *High Volumetric Efficiency in Oil Well Pumping and its Practical Results*, Proc. first mid-year meeting, Division of Production, American Petroleum Institute, pp. 47-61 (June, 1931).

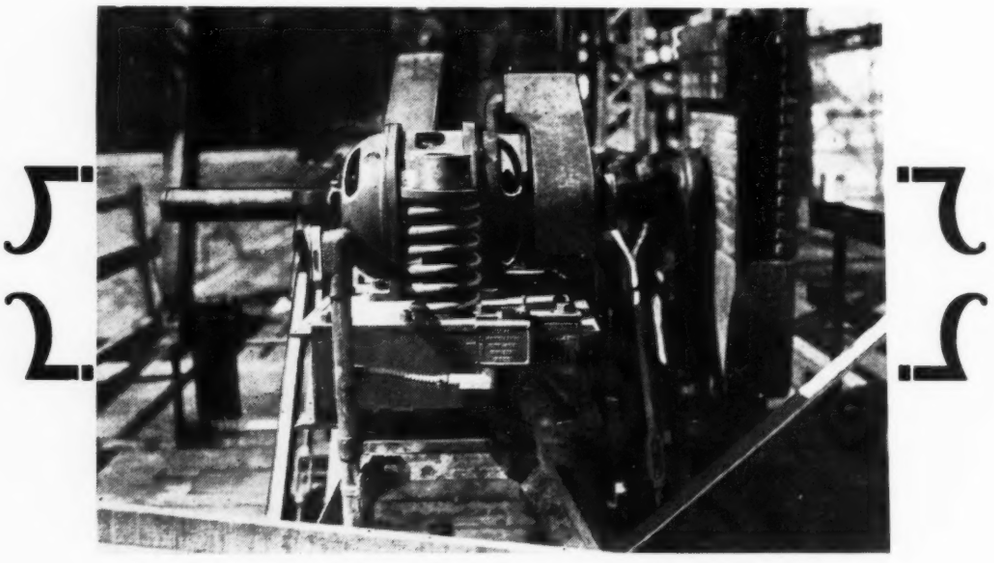


Figure 2. Rear View of Crank-Shaft Pumping Unit. Note Heavy Spring Supports

in this illustration due to the rear cross member of the frame hiding most of the spring. On the up-stroke of the well this lower spring is compressed by the torque generated by the differential load between the well and the counter-balance, while on the down-stroke of the well, the upper spring is compressed due to the differential load between the counter-balance and the well. This suspension provides a very desirable cushioning effect on the entire pumping equipment, and materially reduces the shock loading.

The actual vertical movement of the rear end of the unit will vary with the load, and the design and adjustment of the spring, but apparently a spring compression of about one inch will secure the desired cushioning effect.

Another development complementing this type of suspension is also incorporated into the design. This is an automatic cut-out switch for protection against overload, and it depends upon the vertical movement of the rear end of the unit for its operation. It is a simple type of trip switch cut into one phase of the motor circuit. When the spring compression exceeds a pre-determined amount on either the up-stroke or down-stroke, the excess movement of the rear end of the pumping unit opens the switch and stops the well. The setting of the switch for varied loads is a simple mechanical adjustment easily made, and as the circuit is opened and closed by means of a mercoil tube there is no fire hazard due to its operation.

This pumping unit is running smoothly at 25 strokes per minute in the third hole and the well is producing 630 barrels per day with a three-inch pump set at 4,650 feet. This load indicates a net fluid demand of about 21 horsepower, and as the motor input only shows about 17 horsepower, it is evident the fluid level in the well is several hundred feet above the pump.

Another unit, new also, of the crankshaft type, is suspended directly on the crankshaft and supported entirely by the shaft. (See Figure 3). One end of the main casting or torque arm is keyed to the shaft and the motor and gear are mounted radially on the end of this torque arm. A large sprocket is mounted free on the crankshaft, but is held from rotating by securing it to the jack post by means of compression springs, which provide a cushioning effect on the pumping stroke. The torque arm with motor and gear mounted thereon are revolved together with the crankshaft by means of a chain drive to the stationary sprocket. A special rotating connection is mounted on the crankshaft for carrying the motor circuit. There is a basic advantage in this type of unit by reason of the entire weight of the pumping unit being utilized as a rotating counter-balance. The unit is mounted in the same radial plane with the crank, and the weight of the motor, gear and torque arm exerts a counter-balancing effect of 4,000 pounds at 90 degrees in the third hole. On shallower wells this feature would eliminate the necessity for any counter-balance whatever. This unit is operating a 2½-inch pump at 5,000 feet and producing about 200 barrels daily. The pumping speed is 17 strokes per minute in the third hole, and the unit appears to be operating in a smooth and satisfactory manner.

As a result of new developments in pumping equipment in California during the past year it appears quite probable the next year will witness major changes in the design of such equipment, with the particular objective of reducing shock loading and preventing excessive over-loads, and also of lowering the installation cost of such equipment. This trend in design presents definite promise to operators depending upon the production from deep wells that have declined to the point where the installation and operating costs for pumping equipment are of major importance.

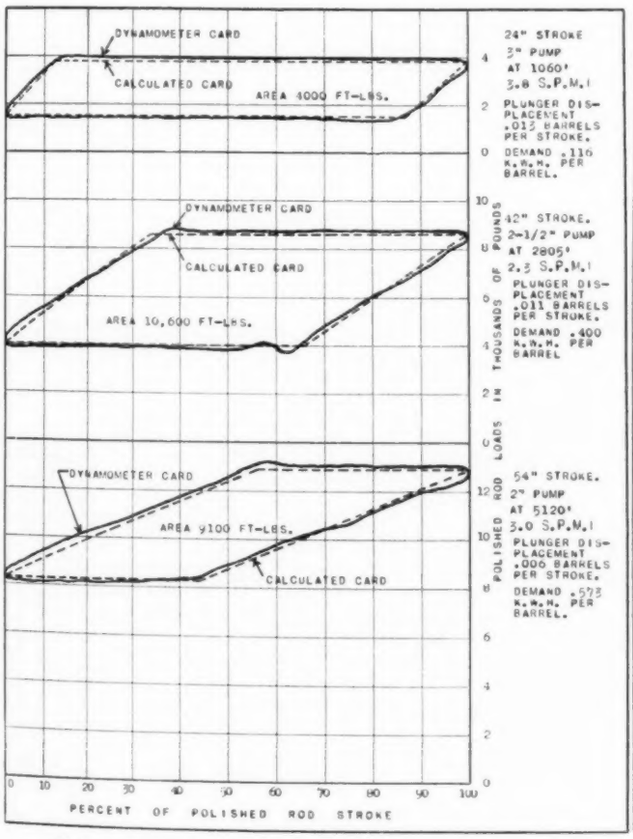


Plate 1. Typical Slow-Speed Pumping Dynamometer Cards

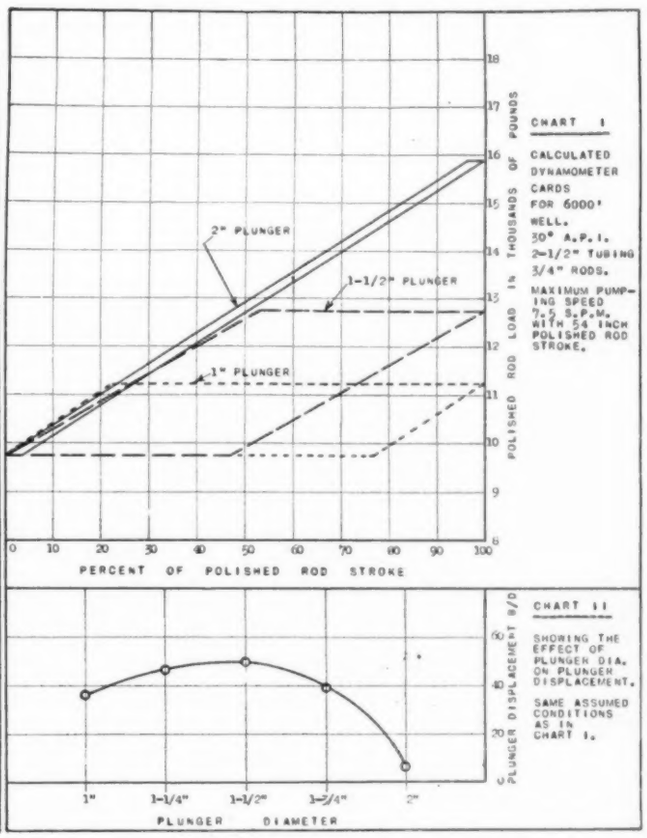


Plate 2. Analysis for an Assumed Set of Data

Tractor With Side-Winch . . .

Saves Time in Tank Construction

A UNIQUE and most interesting new application in oil field tank construction methods is the adoption of a tractor equipped with a live-boom, for the complete handling of the steel plates during tank construction, as well as for lowering the bottom and first ring of the tank to the ground level, after it had been riveted and tested.

Among the advantages found in the adoption of this new application are the remarkable ease with which the tractor can handle the steel plates, including lowering of the tank bottom from the shoring timbers, and the considerable saving in erection time, particularly in the lowering operation.

Using this new application of the tractor, the firm of Joe Sparling, Inc., tank contractors, of Tulsa, Okla., recently completed several large tank building jobs for the White Eagle Oil Company, at the latter's Augusta, Kansas, refinery. It is the belief of J. T. Sparling that, in time, the caterpillar tractor with a live-boom will be a necessary piece of equipment on most tank construction jobs.

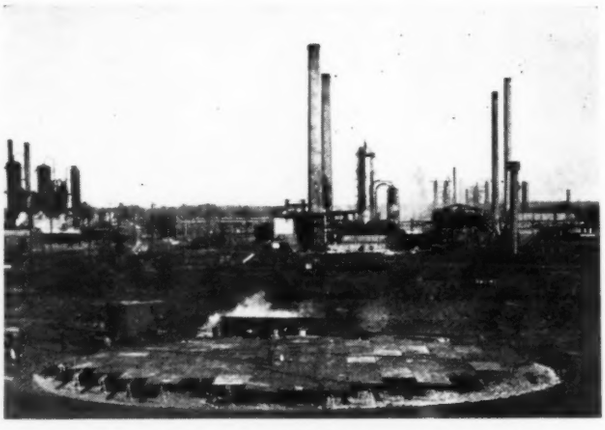
Lowering the tank bottom, usually a time-consuming operation, is performed in much less time and with a smaller number of men when the tractor, equipped with live-boom, is used. At the White Eagle Oil Company's refinery, a 55,000-barrel, riveted tank was lowered by this means in the over-all time of 45 minutes.

The bottom and first ring of the tank were built in the customary manner, being laid on trestles. After the bottom and first ring had been riveted and then tested, cribs were placed around the tank at intervals of approximately every 20 feet. The cribs were built up from 6" x 6" blocks, and on these the weight of the entire tank bottom and first ring eventually rested, for all the trestles were removed from beneath the bottom as soon as the cribs were in place.

At this point of the operation, the usual procedure in the past has been to use two or more 25-ton jacks, and to go around jacking up the tank, taking out a block from each crib, then lowering, and repeating this process until the tank bottom is lowered to the last shoring timber, which is later knocked out by a heavy maul.

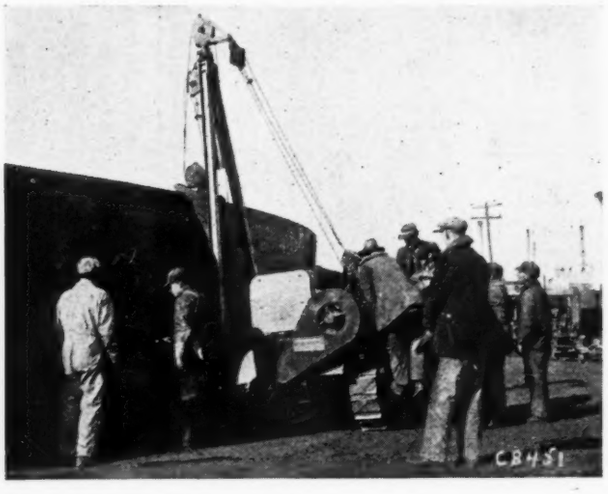
When lowering with a tractor, however, the method used was to raise the bottom with the boom, instead of with the jacks. The Caterpillar operator drove around the tank, while a helper attached the boom to the tank bottom at each crib and removed a block when the tank was lifted. This operation was repeated until the tank was resting solidly on the ground. The tractor, a Caterpillar "Twenty" model, equipped with an All-steel Products Manufacturing Company four-speed, double-drum, live-boom side winch, was then used in setting the upper steel plates of the tank.

In erecting one of the tanks at Augusta, Kansas, the steel used had previously been in service in crude oil storage tanks, but as it was now desired to use it for 30-color gasoline, all the steel plates had to be washed so as to make them suitable for gasoline storage. For washing, a deep vat made from an old condenser box was filled about half-way with a solution of water and Oakite. A steam coil was placed in the bottom of the vat to keep the solution hot, and a tractor was used for lowering the steel plates into the vat. After immersion, they came out ready and suitable for use in gasoline tanks.



Above: Construction of tank bottom; Just beyond which is vat for cleaning steel plates.

Below: Lowering Bottom and First Ring of Side Plates.

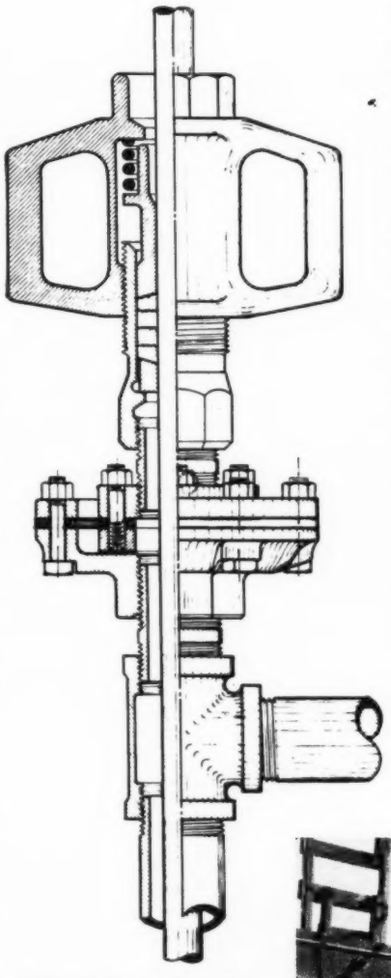


Below: Side-winch swinging plates into position for second ring of 55,000-barrel tank, after it has been lowered to the ground.

Flexible Diaphragm

Reduces Stuffing-Box Wear at Pumping Wells

ON many pumping wells there is excessive wear at the stuffing-box, with consequent wear and tear on the polished rod and annoying leakage. Though much of this trouble can be traced to misalignment, there are many cases in which it is caused by slight angularity of the polished rod, even where a straight-line motion is used. Wear and tear of this sort have been practically eliminated by the Continental Oil Company on pumping wells in Oklahoma and Kansas, by means of a flexible connector unit on the tubinghead, consisting of a regular polished rod stuffing-box mounted on a flexible diaphragm.



Cross section showing the constructional details of the Flexible Connector Unit for pumping wells.

The flexible diaphragm, made from a piece of heavy belting, is inserted between six-inch flanges, and the stuffing-box attached to it by means of two lock-nuts, one above and one below, on a bushing that screws into the tubinghead of the well. Any sidewise movement of the polished rod while the well is pumping as a result of misalignment or angularity, is taken up by the flexible diaphraghm instead of being transmitted to the tubing and wellhead connections.

On one well in the South Ponca field of Oklahoma, pumping at the rate of thirty 48-inch strokes per minute, the stuffing-box packing had to be renewed almost every other day and, just prior to installing the flexible diaphragm, the pumping conditions were so severe that in no case did it run longer than three days without repacking. Although the well was not much out of line, being equipped with a special beam-hanger to obtain straight-line motion, the slight angularity present while the well was pumping, caused the stuffing-box to wear very rapidly at the high speed and long stroke at which the well was operated. With the installation of a flexible diaphragm the trouble previously encountered in keeping the stuffing-box tight has been removed. It is now more than five months since the flexible connector unit was installed on this well and during that time it has been necessary to repack the stuffing-box only four times. This arrangement is still giving the same satisfactory service as when first installed. All that is now necessary to keep the stuffing-box packing tight is to give the stuffing-box gland only one-eighth of a turn every other day.

Since this first installation many more wells have been so equipped. To date, flexible stuffing-box connectors have been installed and put in operation on some 90 wells. Excellent results are being obtained from their use. It appears that by allowing the stuffing-box to move freely and adjust itself to the motion of the polished rod, that 90 per cent of the normal wear and tear to which polished rods and stuffing-box packing rings are subjected is eliminated. Stuffing-boxes sometimes undergo peculiar gyrations while the well is in operation, and no matter how well equipped or lined up, there is considerable whip in the polished rod that does damage to the rod itself, and causes rapid wear on the packing rings unless precaution, such as provided by the flexible diaphragm connector unit, is taken to prevent it.

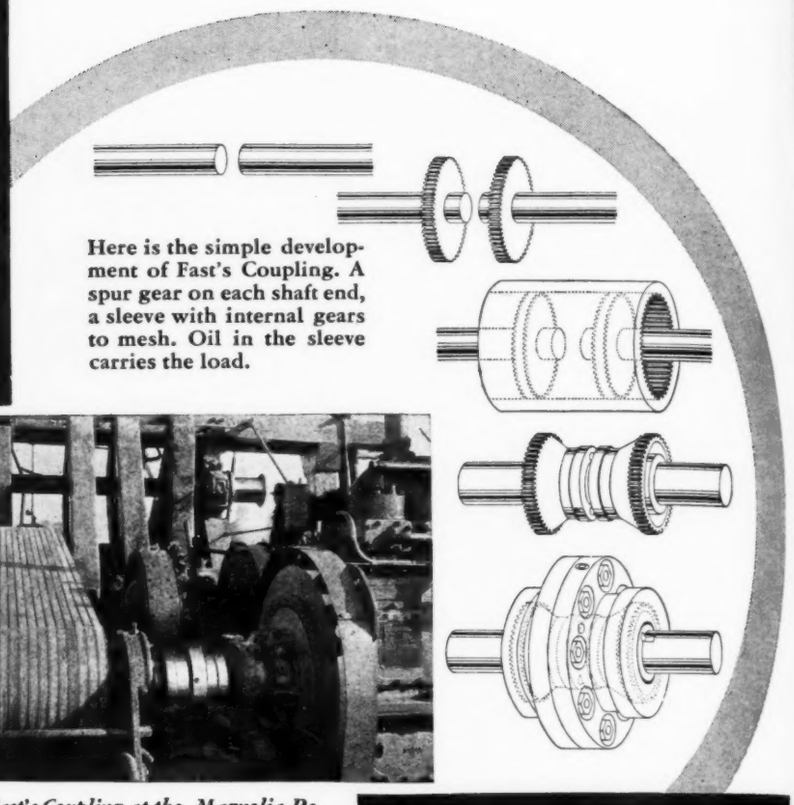
Its use on jack wells operated by a central power has been found extremely beneficial, as it permits adjustment of the polished rod to changes in the rings of the jack line that occur on account of temperature variations.

On the whole the use of this simple device has gone a long way toward solving stuffing-box troubles, with which the average production department of any oil company long has had to contend. It has proved to be a highly economical, effective, and successful method of keeping wellheads tight.

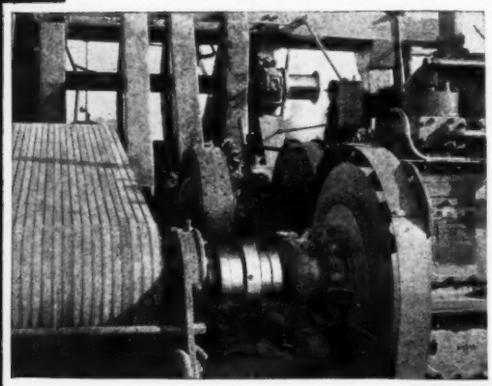
Here is shown the Flexible Diaphragm Connector Unit as it looks installed on a pumping well in Oklahoma

SPECIFY FAST'S *on New Equipment*

Stop Coupling Shut-downs



Here is the simple development of Fast's Coupling. A spur gear on each shaft end, a sleeve with internal gears to mesh. Oil in the sleeve carries the load.



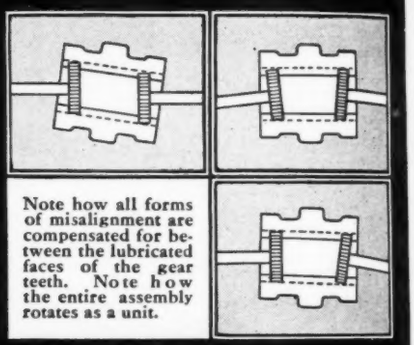
Fast's Coupling at the Magnolia Petroleum Corporation, Wewoka, Okla.

FAST observed that nearly all coupling shut-downs, with their attendant loss of time and stopping of production, were caused by the failure of a flexible pin, spring, disc, washer or grid. "Why not do away with these flexible parts?" he asked. "Then we will do away with coupling shut-downs."

The diagram will show you how well he succeeded. Not a single flexible part to fatigue or fail. Not a single part that must be replaced periodically. Nothing but a simple mechanical assembly, in which all forms of shaft misalignment are compensated for between the lubricated teeth of generated gears. The oil carries the load; there is nothing to wear out.

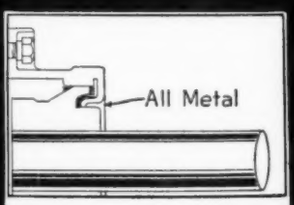
Such a simple assembly will last as long as the connected machines, when oiled periodically like any other piece of transmission equipment—and be utterly free from all the causes that bring on shut-downs.

Wouldn't it interest you to save thousands of dollars for your plant by abolishing coupling shut-downs? Then write today for our catalog that shows a Fast Coupling for almost every need of industry and contains further information about Fast's Self-Aligning Couplings.



Note how all forms of misalignment are compensated for between the lubricated faces of the gear teeth. Note how the entire assembly rotates as a unit.

Permanently Dust-proof



Not a single flexible material, not a single rubber or felt washer is used in Fast's Coupling. All metal to metal contact prevents dust, grit, fumes, or moisture from getting into the working assembly. Due to this exclusive principle, Fast's Couplings never cause shut-downs because of internal wear due to foreign substances.

FAST'S *Self-Aligning* COUPLINGS

THE BARTLETT HAYWARD COMPANY

SCOTT AND McHENRY STS., BALTIMORE, MD.

Wide Expansion Presaged for Gasoline Line Construction

Making a Cold Bend on Gasoline Line in Kansas

WITHIN the past two years significant changes have been made in the transportation of refined products and these presaged the building of several thousand miles of pipe lines for the transportation of gasoline. Last year, alone, approximately 3,000 miles of gasoline pipe lines were completed and put in service. These were extended from Mid-Continent and Eastern refineries to distant markets.

The largest gasoline arteries originate in the Mid-Continent and terminate at markets to the north and northeast. Commencement of long gasoline shipments by pipe lines has been greatly influenced by the improved methods of pipe line welding. With modern methods of welding leakage is reduced to a minimum.

Gasoline has been pumped through short lines for a score of years, having originated on the Gulf Coast. An engine-driven reciprocating pump was employed to force the fluid through a small diameter screw line, and, although short, the line operated under the equivalent of main line conditions.

A few years ago the Shell Company of California built the first long gasoline line, a 100-mile four- and six-inch line, from the Ventura field to its Wilmington refinery. This line was designed to conform to average trunk line working pressures; equipped with automatic devices at both of its pump stations for the control of its prime mover; and equipped with centrifugal pumps to permit keeping the gasoline under pressure from the time it went into the line until it reached the terminal. The line is solid welded and one of the centrifugal pumps is driven by a steam turbine, the other being powered by motor.

Since the successful completion and testing of this line several short-length lines have been built in various sections of the country. It was not until 1930, however, that gasoline line construction was started on a major scale.

The Great Lakes Pipe Line Company, Kansas City, Mo., and the Phillips Pipe Line Company, each announced plans at about the same time to construct arteries to carry refined products. Last year both of these lines, along with others, were completed and placed in service.

The Great Lakes line extended from the Mid-Continent to Northern markets, with its first terminal at Kansas City, Mo. This line has a lateral running to Omaha, Nebr., while the main line branches in Iowa, with one line going to Chicago and the other to the Twin Cities of Minnesota.

The entire line was built under strict construction specifications to insure a tight artery which would operate against 800 pounds pressure. The reciprocating pump stations are powered with Diesel engines.

Location of the stations was made from friction curves calculated from water formulae, corrected for the difference in specific gravity of water and the gasoline to be handled. Using these curves the transporting company had its stations so spaced as to permit pumping direct from one station to the suction line of the station ahead. Subsequent operation test runs have shown that evaporation losses are practically nil when the incoming stream is tied into a floating roof working tank.

Only a few grades of specification gasoline are transported through this system. At each of the terminals ample storage has been erected to care for tank wagon and tank car shipments from that point. Each terminal is equipped with the most modern Ethyl blending plants to permit shippers to blend their premium products.

During construction of the Phillips line the same attention was given to welds to insure perfect joints. In order to secure an absolutely clean line, this company ordered the interior walls of the pipe cleaned at the mill, washed and then capped on both ends with a light metal cap. These caps were removed only when the pipe was lined up for the tack welds. This procedure resulted in a clean line even to the removal of mill scale from the inside walls of the metal.

The Phillips line marked the introduction of two radical departures from general pipe line practice: the driving of centrifugal pumps through gear increasers connected to a gas engine and the fueling of the engine with butane. Butane, formerly waste product to a great extent, is slugged through the pipe line, each station removing a sufficient quantity of the liquid for its own use. This is stored in pressure tanks and used as required. To use the product the control valve on the tank line is opened and the butane is reduced to a rich gas by dropping its pressure by means of regulators. Butane contains approximately 3,100 b.t.u. per cubic foot and the carburetors on the engines are adjusted to obtain the proper air-gas mixture.

The use of what would otherwise be a waste product of the natural gasoline plants, results in an exceptionally economical fuel cost for the various stations. No trouble of consequence is experienced from intermingling of products.

Line designing engineers departed from the accepted practice by driving the pumps through gear increasers. The gas

engines are six cylinder, developing 260 h.p. at 360 r.p.m. The pumps are 3,600 r.p.m. centrifugals. A resilient coupling is placed between the flywheel and the gear increaser to absorb shock, which would otherwise reach the pump, causing it to operate at a non-uniform speed.

The pipe line company desired to pump unblended products through the line, considering it more convenient to blend them at the terminals. At least five varieties of gasoline are pumped through the line at this time. That it is practical to slug these five products without harmful intermingling has been shown by tests conducted on three-inch lines in the field.

Another factor favorable to this practice is that at no time is there a gasoline carried by the line that is suitable for motor fuel. Therefore the efforts of anyone who might want to tap the line to steal gasoline are discouraged.

In this connection most of the pipe line companies handling gasoline guarded against such theft when the first section of pipe was laid. Line walkers were started over the line upon the completion of a back fill. At that time their only duty was to observe the condition of the backfill to make certain no one had tampered with the line. In addition, each of the new lines is equipped with gauging or flow instruments that aid in checking runs and, with these, undue losses are more readily detected.

To handle the five grades pumped through the Phillips line the company has installed various types of storage at the terminal. Tanks consist of those with floating roof as well as spheroid tanks and butane blimps. Blending pumps are provided for making finished products, including Ethyl gasoline, and for loading into tank cars or wagons.

In the East considerable gasoline line construction work was completed last year. Part of this included the completion of the Susquehana Pipe Line Company's expansive system, starting at the Sun Oil Company's refinery at Marcus Hook. The line branches near Lancaster, Pa., with one line going northwest to Cleveland, Ohio, and the other north to Syracuse, New York.

This line reaches into a concentrated market area and also affords a water terminal for shipment of the Sun Company's products in the Great Lakes region. Station equipment consists of motor-driven centrifugal pump units.

In the same general area, the Atlantic Pipe Line Company started an expansive gasoline system and has a part of its projected system in operation. The stations on this line are equipped with reciprocating pumps.

Another of the gasoline systems built in the East last year was the Standard Oil Company of New York line from East Providence, R. I., to markets in Massachusetts. This line is approximately 100 miles long and finished grades of gasoline are pumped through it from tidewater storage to markets.

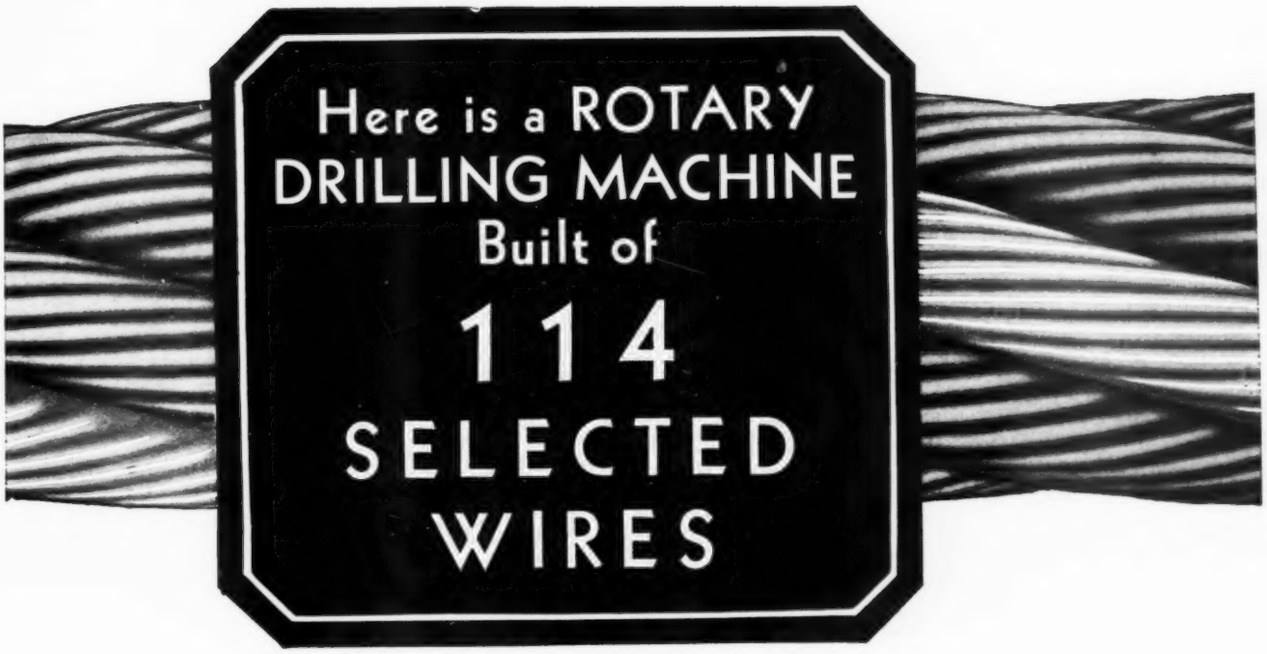
Since the old Tuscarora line was reconditioned a few years ago and revamped for the handling of gasoline, only a small amount of this work has been done. The revamping of this line, however, proved the method practical.

Early this year the Arkansas Fuel Oil Company, of Shreveport, La., leased one of the Texas Pipe Line Company's lines running from the Louisiana area to the Gulf Coast for the purpose of pumping gasoline from Shreveport refineries to tidewater. The line was washed and finished gasoline is delivered to the tidewater terminal through it by one pump station located at the refinery.

These changes in the practice of shipping gasoline have opened the way for far-reaching changes in the distribution of refined products. Already several companies have short welded lines through which gasoline is delivered to large bulk stations a short distance from the refinery. This practice has led several transporters to predict that some future lines will be patterned after gas systems, in that the transporting company will construct small diameter lines from the main line to near-by bulk stations.

Several producing and refining companies are conducting surveys to determine the economics of building gasoline lines to large markets. Some of the existing systems are well along with plans for the expansion of their capacities. Although a relatively new practice among transporting companies, gasoline lines have proved economically sound and a wide expansion in this field is predicted for the future.

General Airplane View of a Gasoline Terminal; Storage and Blending Tanks to the Left, Station in Right Background and Manifold and Loading Racks in Right Foreground



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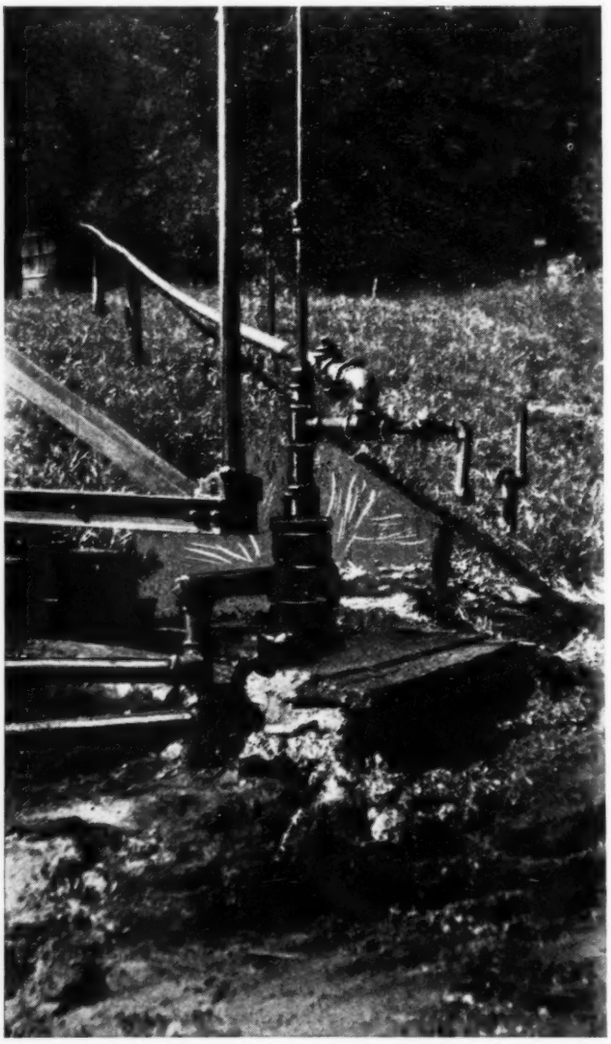
Recent Developments in the Operation of Water-Flood Properties

By PAUL D. TORREY☆

DURING the past two years, the Bradford and Allegany fields, located in McKean County Pennsylvania, and Cattaraugus and Allegany Counties, New York, have been confronted with an over-production of crude which has been responsible for rather radical changes in operating procedure. This condition was brought on both by economic factors, which have influenced the entire petroleum industry, and by the ease with which oil production can be maintained or increased by water flooding methods.

In many respects the technology of water flooding has been improved much more rapidly than the markets for Pennsylvania oil have been expanded. Improvements in efficiency have resulted in higher prices for acreage, which in turn have compelled a more rapid development of properties in order to provide an adequate return on the large sums invested in land and required for development purposes. Without some restrictive measure local overproduction was inevitable, regardless of conditions in other oil-producing states, and the excess oil available elsewhere merely tended to hasten the day when accumulations of Pennsylvania crude in storage began to increase so rapidly that drastic reductions were made in the posted price paid for crude. At first these cuts did not have the desired effect. Many properties had floods in operation in almost every stage of depletion, and the owners, being either fearful that a partial curtailment might materially affect ultimate recovery or on account of financial reasons, continued to produce the maximum capacity from their operations. This attitude was, however, shortly thereafter changed owing to the limited amount of oil storage available, and rather than submit to proration enforced by pipe-line and refining companies, the operators voluntarily agreed upon a general curtailment in production.



Pumping well in the Bradford field in an area produced by water-flooding

Delayed Drilling System and Curtailment

The enforcement of proration schedules made necessary a change in operating technology. Not only was the price of oil reduced over one-half, but the allowable production was so restricted that in certain instances the gross income that could be realized was reduced from 70 to 75 per cent of the normal return. Operating and development expenses on water-flooding properties are factors which cannot be materially lowered without seriously affecting the efficiency of operations, and land costs cannot be reduced; in consequence the operators, being confronted with a condition of limited income and relatively unchangeable fixed charges, were forced to look to methods of production which would not only assure the anticipated ultimate recovery, but which might also increase the recovery to equal or exceed the losses experienced from a diminished daily revenue. Fortunately at about the same time that conditions of overproduction were becoming evident, the delayed system of drilling was being developed in the Allegany field. The results obtained from the use of this system were first described in *The Petroleum Engineer*,[1] and since the publication of that article delayed drilling as originally described or with various modification has been rather extensively employed.

The system of delayed drilling was originally devised to control water flooding action in an oil sand possessing highly variable permeabilities in the different strata. It had been previously discovered by core analyses that under such sand conditions conventional methods of flooding were very inefficient. Flooding action was restricted to the more permeable strata of the sand leaving the tighter parts relatively unaffected, and in consequence the recovery obtained was not in proportion to the amount of oil in the sand.

Principle of Delayed Drilling System

The principle of delayed drilling in very simple. Instead of immediately drilling the oil well in a five-spot square, the water is allowed to migrate through the sand from the intake wells for a predetermined period, which is based upon the rate of input and upon the capacity of the reservoir rock to

☆Torrey, Fralich and Simmons, Petroleum Engineers, Bradford, Pa.

[1] "The Delayed System of Drilling in the Water Flooding of Oil Sands." *The Petroleum Engineer*, December, 1930.

hold fluid, until the sand is entirely saturated. By this procedure the oil is first concentrated toward the center of the five-spot square in the more permeable horizons and after these are saturated with fluid and with a continued maintenance of pressure at the intake wells, flooding action, with a similar concentration of oil, is forced in the less permeable beds. When a condition of complete sand saturation is approached a marked diminution in water input indicates that the capacity of the sand to hold fluid has been reached. At this time the oil well can be drilled, or if market conditions are not favorable, the drilling may be further delayed without any detrimental results.

Impressive Increases in Recovery

The results from the first delayed flood were very satisfactory. Oil recovery was increased from approximately 1,300 barrels per acre to over 4,000 barrels per acre. This might appear to be rather spectacular and subsequent operating experience has shown that such large increases cannot be anticipated on all properties. However, it can be stated with a reasonable degree of certainty that delayed drilling may be expected to increase oil recovery in sands possessing highly variable permeability as much as 200 per cent and in more uniform sands from 20 to 50 per cent.

Following the first successful application of delayed drilling the system has been used under widely varying conditions on several properties in the Bradford and Allegany fields. The ultimate recovery from many of these floods is still rather indefinite, owing to proration, but where the system has been intelligently applied the results have been uniformly impressive. Delayed drilling not only forces a more nearly complete concentration of oil in the five-spot square, but it also takes advantage of the powerful propulsive force of expanding gas. Under conventional methods of intensive development the gas held along with the oil in the pore spaces of the sand is rapidly depleted, but in the delayed system it is forced back into solution in the oil until the pressure is relieved by the drilling of the producing well. When the pressure is relieved the gas comes out of solution and expands at a uniform rate throughout the entire area of concentrated oil, forcing it toward the point of lowest pressure; i. e., the producing oil well. This is made possible by the fact that when the sand approaches a condition of complete saturation, capillary control of fluid movement through the pore spaces changes to hydraulic control so that not only is a uniform pressure established throughout the sand body but also as long as pressure is maintained at the intake well such voids in the sand that are emptied of their oil content by movement toward the producing well are immediately filled by advancing water. The establishment of a uniform pressure throughout the sand body not only makes hydraulic displacement possible, but it also tends to establish uniform lines of fluid movement toward the oil well from all parts of the five-spot square, rather than along lines of elliptical pressure effects such as probably exist where there is a constant relief of pressure. Such a condition therefore tends to eliminate, at least in part, the ever present danger of by-passing and trapping large volumes of oil in areas where the pressure effect is limited.

Low temperatures in the Bradford field necessitate covering water meters in winter to prevent freezing. Here is shown the box covering used, packed with spent Fuller's earth.

Careful Planning Necessary

The successful application of delayed drilling requires very careful planning and continued attention. It is obvious that a uniform water input must be maintained at each intake well in order to prevent the concentration of the oil off-center. In addition, it is very important that all old holes be securely plugged, since any relief in pressure within the limits of the five-spot square will defeat the main purpose for which the system is employed. Some difficulty has been experienced in the drilling-in of the oil wells. Delayed wells will ordinarily flow when first completed or after the sand is shot with an appreciable loss in oil. This difficulty has been partially removed by temporarily reducing the pressure at the intake wells for a few weeks prior to the drilling-in of the well and as soon as it is completed by increasing the water pressure to the point where it had been normally carried.

Although delayed drilling was developed at a most opportune time, it could not be immediately employed on all properties when proration schedules went into effect, owing to the fact that in most cases floods in practically all stages of depletion were already in operation. Since only a limited amount of oil could be produced the production could be controlled either by entirely shutting off the water in certain intake wells or floods, or by materially reducing the production from each well. The first procedure can be successfully applied to line floods and to intensive floods which are still in an early stage of depletion as long as the producing wells are systematically pumped, but it appears to be hazardous for floods in an advanced stage of production owing to the danger of trapping oil in some of the less permeable members of the sand body by the removal of pressure at the intake well. The production of a limited amount of oil from each well has in general proved to be more satisfactory. This can be accomplished by back-pressuring at the oil well. The fluid is allowed to build up in the hole and such oil as may be required is flowed from the well at periodic intervals. Back-pressuring and flowing are closely allied to delayed-drilling. As long as back-pressure is maintained the migration of large volumes of fluid through the more permeable parts of the sand is, at least in part, restrained. Some concern was originally expressed that the presence of water over the face of the sand might have a harmful effect, but it has been

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found that unless a flood was in a very advanced stage of production, as soon as a column of oil was built up in the hole, which would establish a condition of fluid equilibrium, the amount of water coming into the oil well was materially reduced. It is, however, believed that back-pressuring and flowing will not force as complete a concentration of oil toward the center of the five-spot square as delayed drilling, for as soon as hydraulic control is established in any one bed of the sand body the relief of pressure by flowing will tend to influence more rapid fluid movement through these beds, rather than through the less permeable members where flooding action has only been partially established.

The same precautions required for successful delayed drilling are applicable to back-pressuring and flowing. All old wells should be plugged, and in addition the tubing should be set with a packer near the top of the sand in order to prevent the loss of oil into porous formations which may exist between the bottom of the casing and the top of the oil sand, and also to eliminate the possibility of lifting the water string of casing due to the increased pressure while the well is shut in. Where high water pressures are used the packer must be cemented, but this procedure has very undesirable features since it will hinder the pulling of the tubing for salvage or to clean out paraffine.

Experimenting With High-Water Pressure

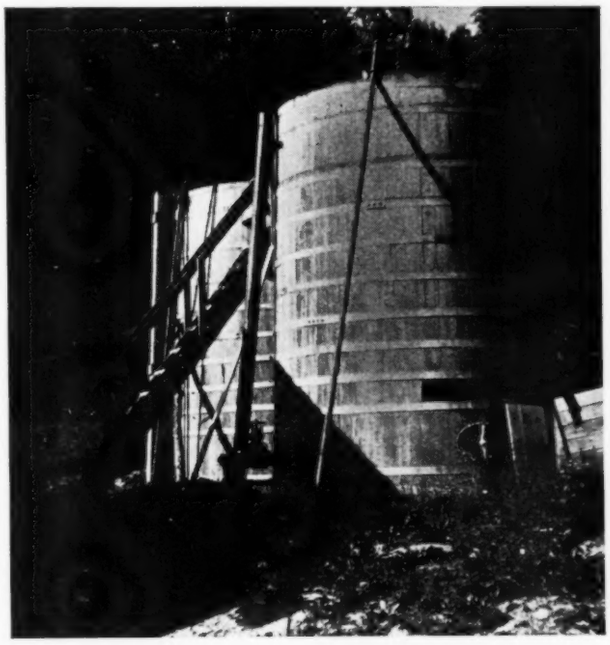
On most back-pressuring and flowing operations conventional water pressures at the intake wells have been employed. Some experimentation is under way at the present time in the use of higher water pressures; from 2,000 to 3,000 pounds per square inch at the top of the sand. These tests have not been in operation for a sufficiently long time to give comparable results. However, the results obtained so far have indicated that high pressures will accelerate depletion owing to the large amount of oil that is rapidly forced into the producing well. The application of high pressures requires the use of special tubing and also very careful control of back-pressure and water input, in order to prevent a premature migration of water through parts of the sand possessing high permeability.

Owing to proration it has been impossible to compare the results that may be obtained from back-pressuring and flowing with conventional water flooding operations. Very few back-pressured wells have been allowed to produce to their full capacity and then only for a limited period. The operating costs on back-pressured floods are materially lowered and it is found that the ultimate recovery of oil is equal to or greater than that obtained by the production methods employed in the past, and also that development costs can be appreciably reduced by the elimination of powers and pumping equipment.

Water Treatment Important

Outside of the development of delayed drilling and back-pressuring and flowing, the most important recent improvement in water flooding technology is the treatment of the water to prevent the plugging of the sand by matter carried in suspension. The water used for flooding purposes is primarily responsible for the displacement of the oil from the sand and it has become increasingly evident that the quality of the water may have a most important bearing on the effectiveness of this displacement and consequently upon the recovery of oil. Any water purification for flooding purposes involves the removal from the raw water of any substance or property which would tend to make it plug the pore spaces and so impede a constant movement of the water through the sand body. An adequate supply of pure water is an absolute necessity, particularly when it is realized that the water requirements of an intensive flood are sometimes in excess of the rainfall over the operated area.

Most ground waters contain a small amount of suspended matter and varying amounts of soluble iron and other mineral salts. Under the old system of flooding, where the water did not come in contact with the atmosphere, plugging of the sand probably was not a serious problem. However, with the adoption of intensive methods of development, resulting in a corresponding increased demand for water, the old system of subsurface floods was abandoned and the water required for the operation is now flowed from shallow water wells into tanks from which it is pumped through a system of pipe lines to each intake well. Although this method insures an adequate supply of water to each intake well it has the great disadvantage that the soluble ferrous salts are oxidized to insoluble ferric compounds when the water is flowed by compressed air. The formation of this insoluble matter has resulted in the plugging of the sand in many wells and it soon became evident that these compounds must be removed before the water was turned into the sand. This has been accomplished by the use of sand filters with alum as a coagulent.



Water tanks used with filter units for the treatment of water for flooding operations in the Bradford field in Pennsylvania.

The filter alone, however, does not entirely solve the problem of sand plugging inasmuch as the water, even after leaving the filter, is essentially saturated with carbon dioxide and oxygen which will react with the steel tubing of the pipe line, between the pumping station and the intake wells, to form insoluble iron compounds which are practically the same as those which originate from the oxidation of the ferrous salts in the raw water. For this reason the flowing of water for flooding purposes by compressed air is being gradually abandoned and turbine pumps substituted for air-lifts. By this method the water is not aerated and consequently does not corrode the pipe to any appreciable extent. Where air-lifts are still in operation it is necessary to use either non-corrosive alloy steel pipe, which materially increases development expenses, or slowly to run the water coming from the filter through a tank filled with small pieces of marble to remove most of the carbon dioxide, or to deposit a thin film of calcium carbonate on the inside of the pipe by artificially increasing the pH of the water by the addition of an alkali.

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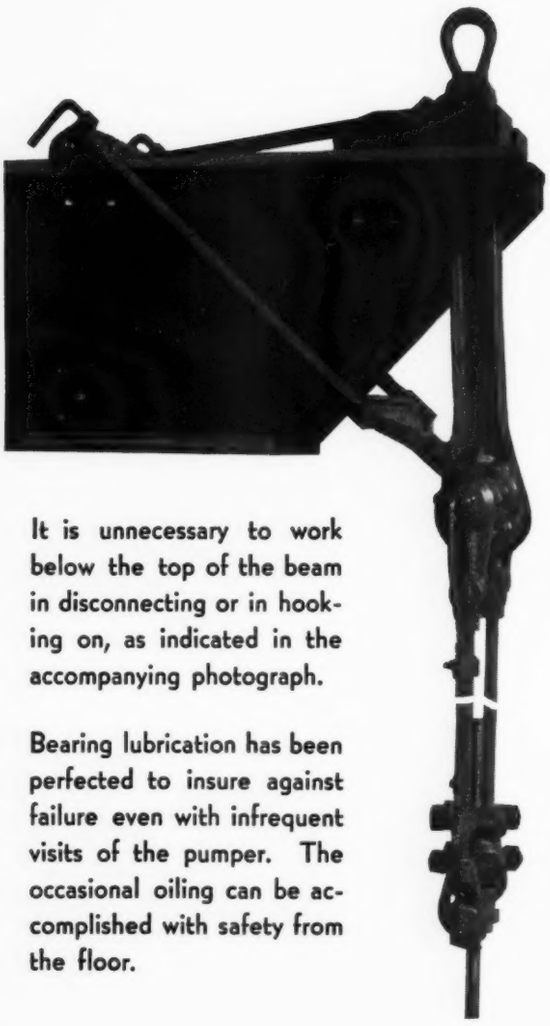

It is unnecessary to work below the top of the beam in disconnecting or in hooking on, as indicated in the accompanying photograph.

Bearing lubrication has been perfected to insure against failure even with infrequent visits of the pumper. The occasional oiling can be accomplished with safety from the floor.

The Type F Beam Hanger comprises a complete connection between the walking beam and polished rod. It supplies an improved bearing connection, minimizes deviation from a straight lift, and furnishes a connection which can be moved readily to clear the well for pulling operations.

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Two Alcorn furnaces being constructed in a refinery at Houston, Texas

The Octane Rating of Pennsylvania Gasoline

By H. A. SPIEGELMAN
Pennzoil Company

THE octane number rating of competitive price gasoline is steadily increasing. The average rating of gasoline samples taken at Pittsburgh follows:

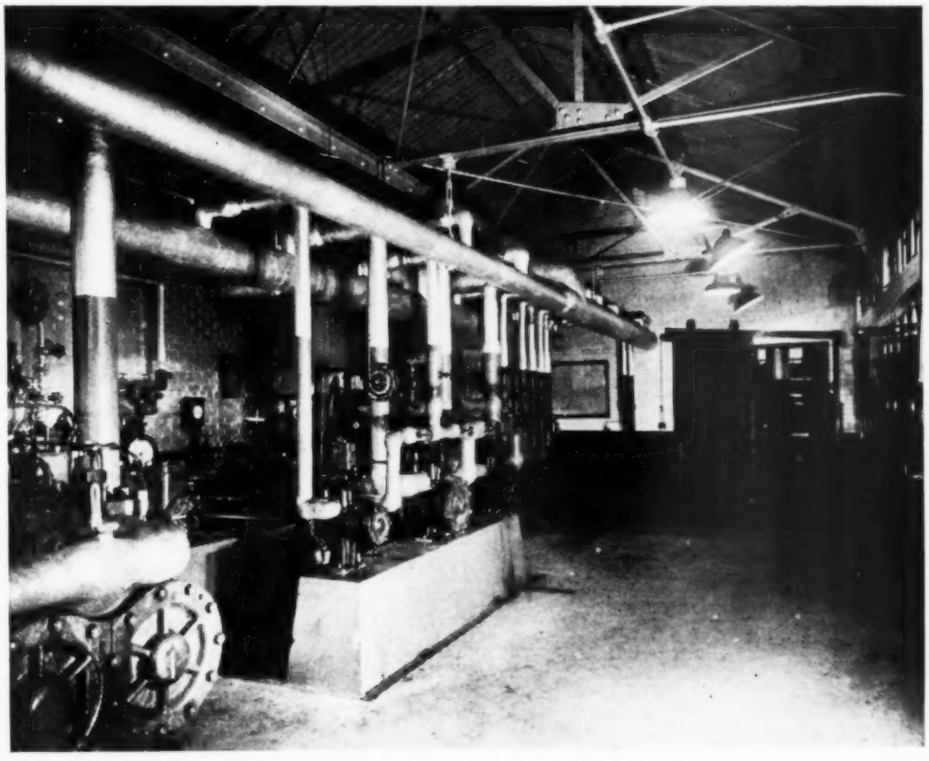
1929	57 octane
1930	64 octane
1931	68 octane
1932	70 octane

The octane rating of motor gasoline here ranks with the best in the country. This fact is surprising in view of the fact that Pennsylvania straight-run gasoline has a low octane rating before it is blended with cracked gasoline, or Ethyl fluid.

Until a few years ago the public paid a premium for 68-70 gravity gasoline. This averaged only 57 octane number. Motor gasoline was of the order of 64-66 gravity. There was no need for a specification for knock rating. The low compression engine of that time did not demand it. The Pennsylvania straight-run gasoline has the highest API gravity, and consequently with the gravity specification it brought a premium price. Mid-continent gasoline of the same boiling point range shows a four-degree lower API gravity, and California gasoline is four degrees lower than this. Consequently a 68-70 API gravity specification was practically impossible for other than a refiner of Pennsylvania crude to meet. Conditions soon changed. The high-compression engine demands a gasoline of high octane rating. Western straight-run gasoline tests 66 to 67 octane number, whereas Pennsylvania straight-run gasoline averages 50 octane number. This created a difficult problem for refiners of Pennsylvania crude oil.

The hilly topography of this part of the country and the increased compression ratio of the modern engine soon showed the motoring public the logic of using a fuel that does not detonate. Cracked gasoline, Ethyl fluid, benzol, and naturals were used in order to improve the octane rating of Pennsylvania straight-run gasoline.

The anti-knock properties of the various fractions of Pennsylvania gasoline were first investigated. It was found that the octane rating was improved by lowering the end point of the gasoline. The straight run gasoline was fractionated into ten per cent cuts. These fractions were blended back with a standard reference fuel. The knock rating became worse as the fractions became heavier, reaching a maximum and maintaining this maximum for the heavier fractions. With the use of a 35-foot column, very narrow cuts were taken. Those fractions having the lowest densities and refractive indices have the highest octane rating. Fenske found that even when several fractions were taken at the same temperature (within 1 deg. F.) large variations in gravity and knock rating were obtained. Lowell, Campbell and Boyd found a straight line function for different classes of con-



Control room for cracking unit in a Pennsylvania refinery

stituents of straight-run gasoline. The straight chain paraffins showed a corresponding decrease in quality of knock rating as the boiling point increased. Butane has a better knock rating than pentane, and pentane better than hexane. Among the straight chain isomers 2-methyl propane shows a better rating than 2-methyl butane, likewise 2-methyl butane is better than 2-methyl pentane. Also methyl pentane has a higher knock rating than hexane, its isomer; and dimethyl butane even higher than methyl pentane, another isomer. The tri-methyl and tetra methyl isomers show increased octane equivalent ratings with increased methyl groups. These properties give an anti-knock analysis of Pennsylvania gasoline.

Checking batch still, battery, and pipe still operations, it was found that knock rating of straight-run gasoline is a function of the fractionating efficiency. High and low octane isomers are present throughout the fractions. With the bubble plate type of tower lower end point has been resorted to in order to raise the octane rating of straight-run gasoline. A gasoline of 45 octane number at 400 deg. F. end point was 50 octane at 370 end point and 60 octane at 305 end point. Another was 50 octane at 370 end point and 61 octane at 330. The octane rating of straight-run gasoline to 370 deg. F. end point from various Pennsylvania crudes is:

Bradford	52 octane
Oil City	51 octane
Eureka	48 octane
Buckeye	45 octane

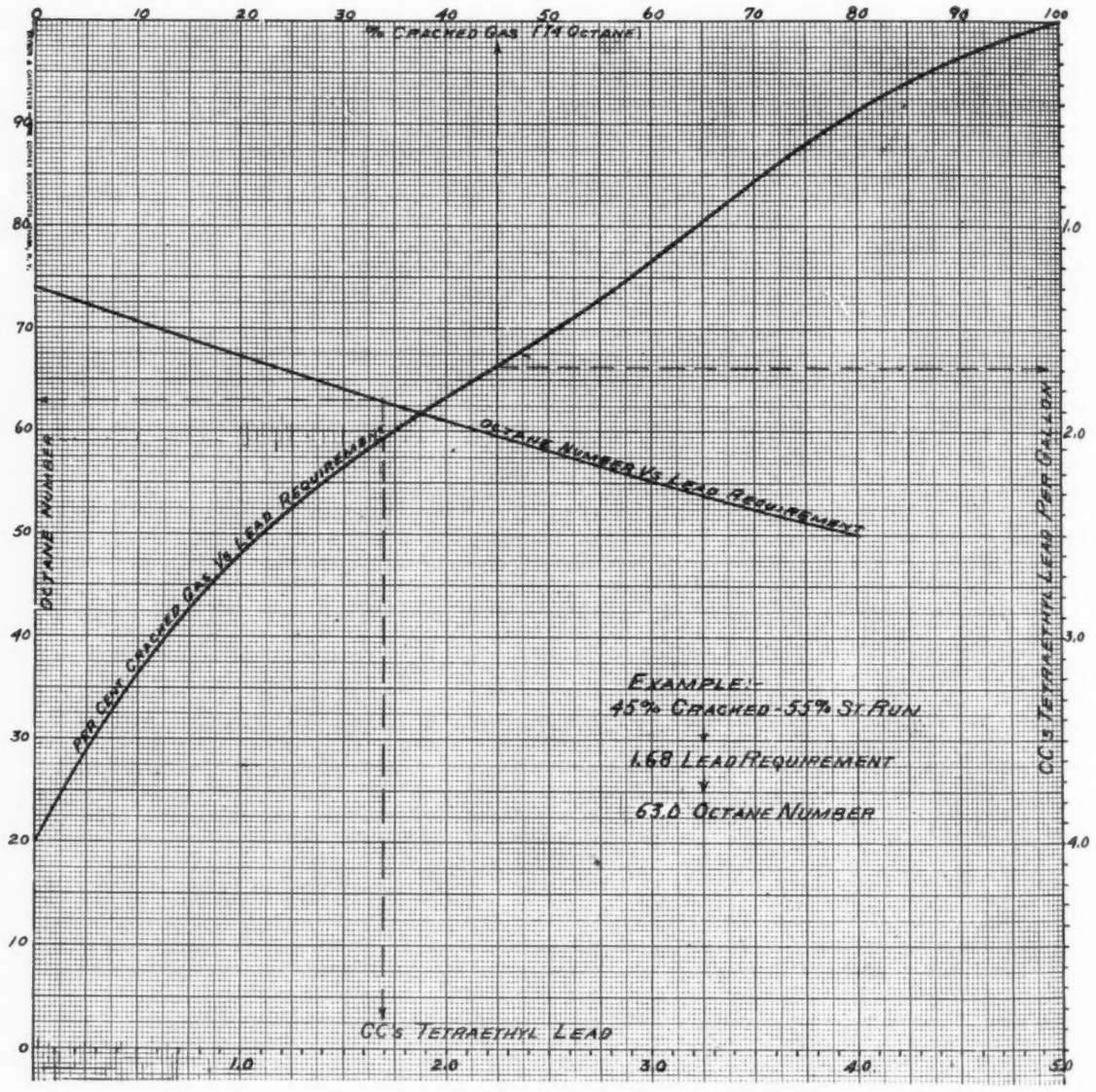
The straight-run gasoline is blended with high octane cracked gasoline before marketing, or with Ethyl fluid for Ethyl gasoline. A blend of straight-run and cracked gasoline of 60 octane will require about 3 c.c. of tetra ethyl lead to make 78 octane standard. The octane rating of cracked gasoline obtained by cracking various charging stocks follows:

Pennsylvania straight-run	75 octane
Pennsylvania naphtha	75 octane
Pennsylvania kerosene	74.5 octane
Pennsylvania fuel oil	74-75 octane

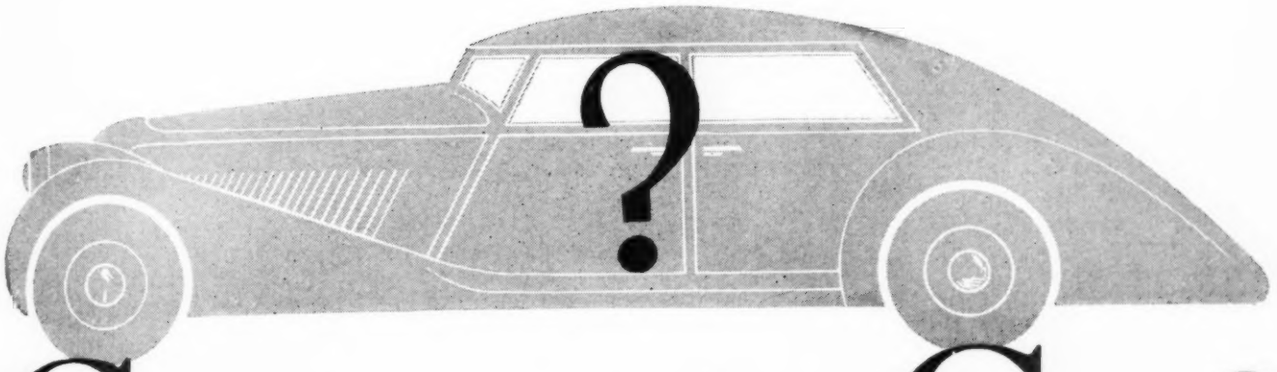
Reducing the end point of the cracked gasoline will produce a 78 octane number from the above charging stocks.

The gasoline is stabilized to 12 pounds maximum Reid vapor pressure during the winter and to nine pounds in the summer. There is a loss of one octane number for a three-pound drop in Reid vapor pressure. Acid treating reduces the octane number according to the quantity of acid and the treating temperature.

The absorption gasoline recovered from the cracking unit has an exceptionally high octane rating. Based on calculated values obtained by blending 50 octane straight run with absorption gasoline the latter has an octane rating of 125. Amylene has a calculated rating of 150 octane. A half and half mixture of tri-methyl ethane and methyl ethyl ethane has a calculated value of 140 octane.


% Cracked Gas (74 Octane)
Octane Number
Per Cent Cracked Gas Vs Lead Requirement
Octane Number Vs Lead Requirement
Example:-
45% Cracked - 55% St. Run
1.68 Lead Requirement
63.0 Octane Number
CC's Tetraethyl Lead
CC's Tetraethyl Lead Per Gallon

Graph showing susceptibility to lead of Pennsylvania Cracked Gasoline



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HIGH compression is here—super-compression is coming! Practically every motor manufacturer is already building high compression engines—but few compression ratios are sufficiently high to take *full advantage* of the fuel that they require: Ethyl Gasoline.

Before very long some manufacturer is going to market a super-compression motor with performance characteristics and fuel economy that will shame competitive cars.

Such a car is entirely practical. It can have *more* power, *faster* acceleration, more power per gallon of fuel consumed, and better all-round performance. Super-compression will, no doubt, present some new problems, but so did four-wheel brakes and free wheeling. Automatic spark control, automatic clutch, easy shift transmissions—all developed from paper dreams. The same men who made them realities *can* build a super-compression car—for all we know they are *already* building it.

The reason for developing super-compression is obvious. It means more sales. A thorough review of the requirements of super-compression shows no reason for delaying the production of such a car.

Greater attention must be paid to the casting and machining of cylinder heads, of course. Even slight variations in the volumes of small clearance spaces produce appreciable differences in compression ratio.

There is no bearing problem to be solved. Crank pin bearing loads are smaller at high speeds in super-compression engines because the increased gas pressures oppose, and therefore decrease, the high inertia forces which are the true cause of bearing failures.

Radiator capacity need not be increased since cooling water temperatures actually *decrease* as compression ratios are increased.

Super-compression engines must have fuel of HIGH anti-knock value. Such a fuel is available on every highway and byway today. The present anti-knock standard for Ethyl Gasoline is sufficiently high to permit compression pressures much higher than the present average.

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Motor Transport Records Prove Valuable

By R. F. FIKE☆

IN dealing with motor transport problems from a fleet owner's standpoint, technicalities must be laid aside; due to the variety of personalities of operators. Practical and easily understandable suggestions and rulings must be incorporated in order to secure best results. A large percentage of car and truck operators are not mechanics and mechanical terms are confusing and expensive if attempted by the average operator.

Regardless of how much engineering effort and precision has been built into the equipment, if you fail to build your operator's common sense to its highest point of interest and efficiency you are certain to have excessive costs in its operation.

Coöperation is not a sentiment; it is an economic necessity, especially in these days of readjustment. Failure to coöperate in the reduction of operating expense and of giving careful consideration to company rulings practically amounts to disloyalty. With all operators realizing that every unnecessary expense has a direct bearing on his pay check as well as the permanency of his position, causes a more careful attitude in their operations and also makes their company's position more secure.

It is the aim of our department to create interest, and at the same time simplify the operator's task, as in each case he has other departmental operations and reports to take care of each month. No other department's operations, especially in the oil industry, connects up with all departments as does motor equipment, as this equipment has a direct bearing on each department's cost of operations.

Coöperation is not a "one-way ticket"; it must come from both directions. Too often, reports are required of employees and as they never hear from them they are of the opinion that these reports are of no importance. It has always been the thought in my company's motor transport department, that each report required of an operator should be carefully analyzed and the operator given some positive proof of its receipt and importance to us, and we have built our department around such reports.

Each month every vehicle operator is advised as to his rating from a percentage standpoint and is shown his expense for the month and for the year as it accumulates. Outside of gasoline and oil, and one or two other items, the great majority of automobile operators have no thought or knowledge of their expense, and our experience has shown us that men who are really interested in their positions appreciate this information. In closing the year, we show each operator, every item of expense, in detail, and also show how other operators driving the same class of equipment have done, so he can see whether he is above or below the average, which gives him an incentive to improve in his next year's operations.

These reports, in addition to showing each operator where he stands, also frequently lead to the discovery of the cause of high expense. One driver may learn in what item or items he is above the average in expense, and he may devote more thought to reducing that particular expense factor. Still another value from these records is a complete history of each car or truck and each piece of equipment attached to it, and not rarely we find some small piece of machinery is being frequently repaired, whereas in the long run it will be cheaper to purchase new equipment to replace the troublesome one.

The supervision of a motor transport department is not a mechanical operation but rather one of personal interest in operators. In order to accomplish the most economical results operators must be brought into the picture in a big way, and we find such reports as we compile to be very beneficial.

Form M-92—500 Bks.—1-30—Petrol.

MID-CONTINENT PETROLEUM CORPORATION

Motor Vehicle Monthly Operating Report

Car No. .....

Month Ending ....., 193 .....

Where used

What kind of work

No. of days operated during month

" Times Completely greased during month

" " Crankcase oil changed during month

" " Water put in battery during month

" New tires for month

" " tubes for month

Miles traveled during month

Total Speedometer Reading

	From Co. Pumps	Purchased Outside	TOTAL
No. Gallons Gasoline Used			
No. Quarts Oil Used			

General Condition of Car:

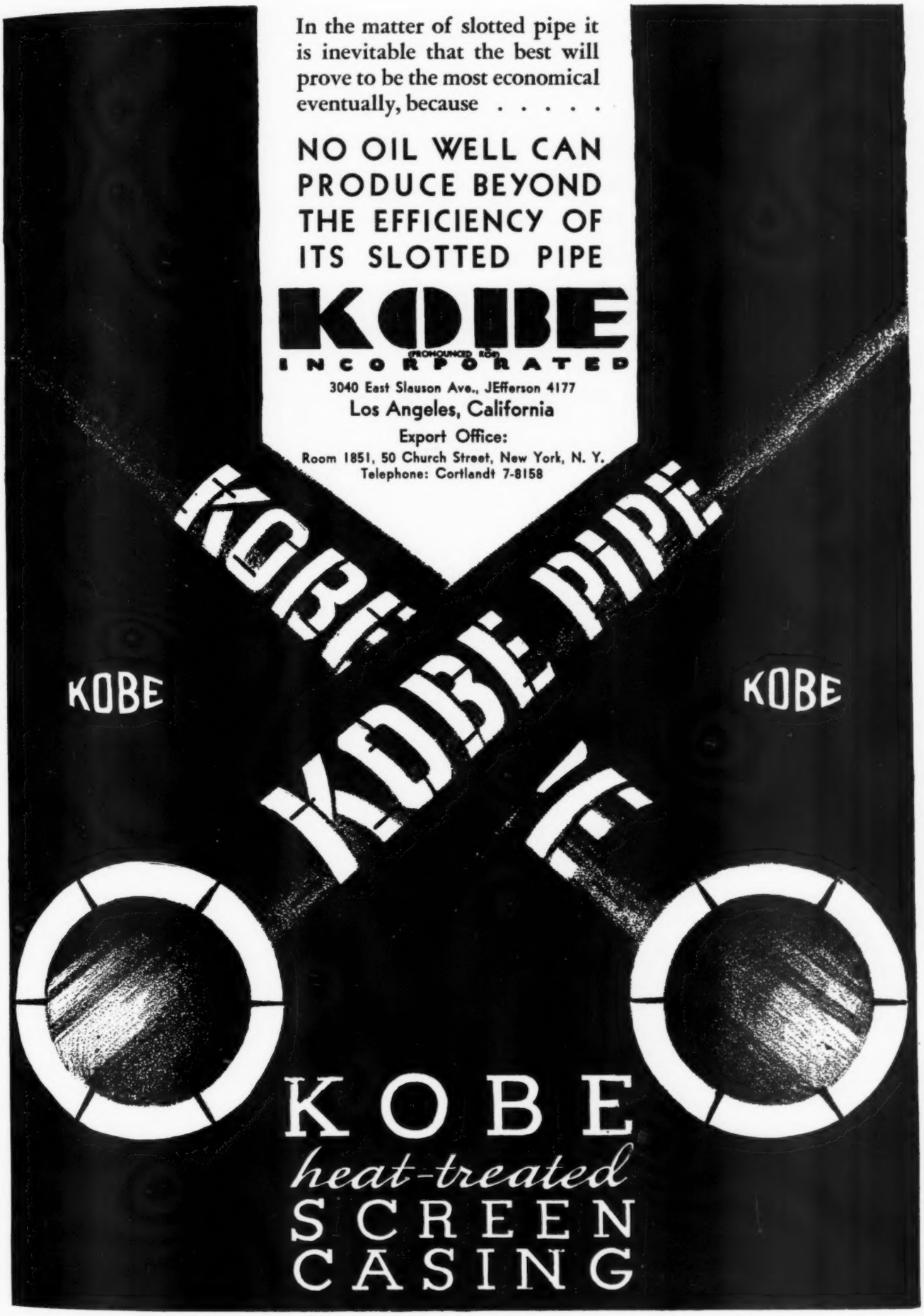
Driven by .....

Mail address .....

Approved by .....

Fill in This Report Promptly at End of Each Month, Forwarding Original to Motor Transportation Office, Box 2025, Tulsa, Oklahoma

☆ Superintendent, Motor Transport Department, Mid-Continent Petroleum Corporation.


In the matter of slotted pipe it is inevitable that the best will prove to be the most economical eventually, because . . . . .
NO OIL WELL CAN PRODUCE BEYOND THE EFFICIENCY OF ITS SLOTTED PIPE
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Developments in
Gas Measurement and Regulation

By D. A. SILLERS☆

D. A. SILLERS

DEVELOPMENTS in gas measurement and regulation during the last few years have been many and varied and are in evidence from the time the gas leaves the sand at the bottom of the well to the time the gas has been sold to the customer and the volume computed in the office. The production of natural gas through siphons is now very general practice. Where liquid is a problem the use of siphons has greatly prolonged the life and the profitable production of many wells and fields. Where the operating pressure of gas wells is exceedingly high and must be regulated to line pressure, a number of heaters have been designed to safely overcome the refrigeration due to expansion. Recently a method using bottom hole chokes has been devised to accomplish this regulation at the bottom of the hole. This method has been found to be exceedingly satisfactory in operation. It lowers the working pressure on the surface fittings and eliminates the possible fire hazard incident to the use of heaters around very high pressure gas.

For several years the Bureau of Mines and the American Gas Association have been experimenting with methods of arriving at the open flow or potential of a well, without the danger and waste of making an open flow test. Reports on the progress of this work have been published and they describe the back pressure method of arriving at the potential of the well and the very practical methods and computations which are required. It is expected that, in the near future, this method may be put into general use and thus eliminate one of the most hazardous and wasteful operations in the gas industry. The Reid open flow tables are now in very general use for calculating the open flow of a well. These tables take into account the static or side pressure in the stream of gas and the effect of critical flow, and thus correct large errors in previously published tables.

On the high pressure well meter it has been found that welded meter piping eliminates the small leaks in screw fittings which so often result in the orifice meter freezing up during cold weather. Figure 1 shows a set of piping with welded tees and ells of bent tubing. Steel needle valves are used and the bodies are screwed tightly to the tubing and then bronze welded. The only threaded connections are those on the nipple from the union into the meter.

During the last year seven-day clocks have come into very general use on well and main line meters. This results in a very considerable reduction in the cost of changing charts and the automobile expense in getting to the meters. It also cuts down the work of chart calculation in the office and is evidently as accurate for the purpose as the 24-hour record.

The controversy between specific gravities obtained by use of the effusion bottle and those obtained by use of the balance has largely subsided. A committee from the American Gasoline Association, working with the Bureau of Standards has recommended the use of the spring suspension type of balance, and this instrument is also in very general use in the dry natural gas fields. Recording gravitometers are now available which are reliable in operation, and which correct for variations in barometer and temperature.

A number of orifice fittings are now on the market which enable the operator to change the orifice plate without shut-

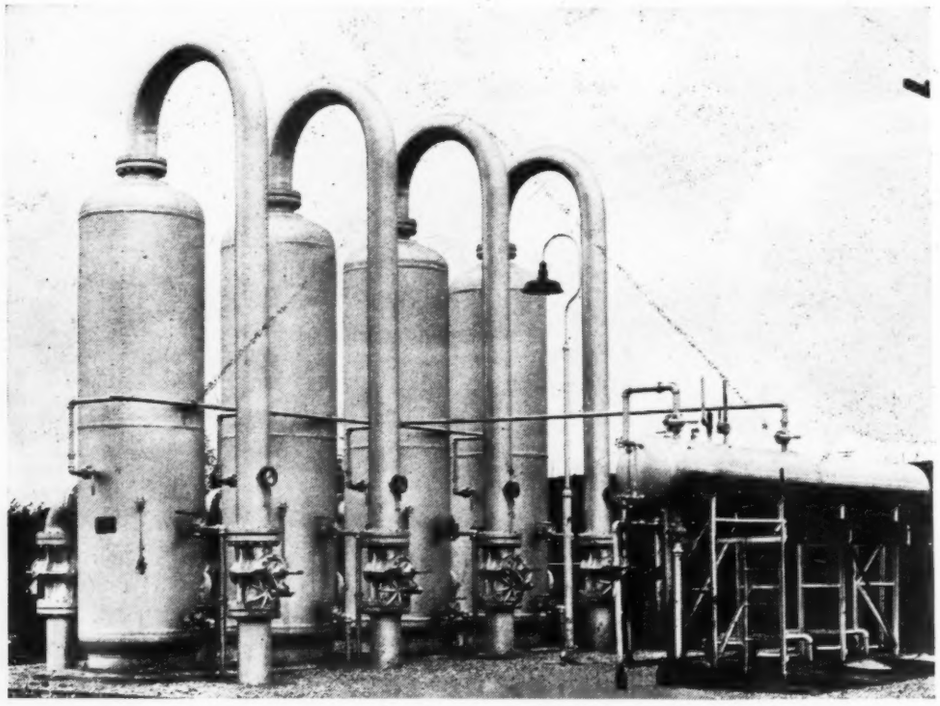

Figure 2. Gas Cleaning Installation

☆ Superintendent Gas Measurement, Lone Star Gas Co., Dallas, Texas.

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ting off the line or requiring a by-pass in the installation. Some of these fittings contain two orifice plates and a change can be effected between these two with a minimum of work. Another orifice fitting is now on the market in which a plate is lowered across the face of a round orifice by means of a hand wheel which operates exactly like a gat valve. The wheel is locked in position, the position of the plate is indicated and a coefficient is supplied for each position of the plate.

Along the pipe line right-of-way we find a domestic meter which has been designed to operate at 20 pounds and which is supplied with an index reading directly in four or eight-ounce gas. This makes it possible to install a high-pressure regulator and the meter on the right-of-way, supplying gas to a consumer at some distance with small diameter pipe. The service regulator is then located on the consumer's premises.

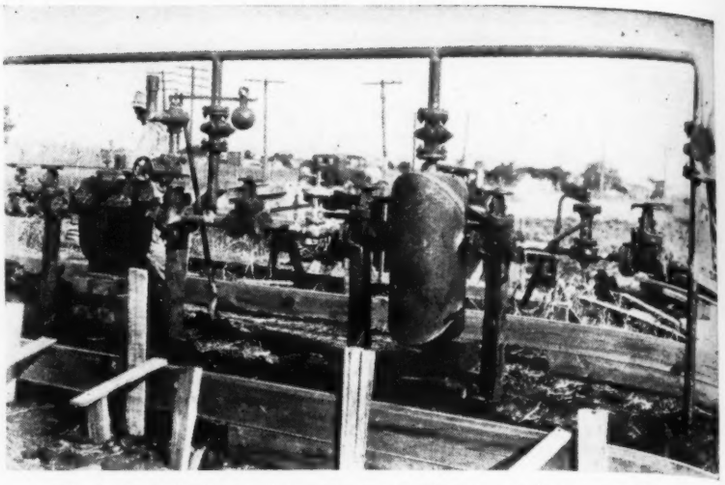

Figure 5. Multiple Regulators showing Cushion Leader between high and semi-high regulators (during construction)

Coming to the city gate and industrial regulating and measuring stations, we find many stations equipped with gas cleaners which remove the dust and dirt which cuts out regulators, builds up on orifice plates, and interferes with the proof of domestic meters. A large gas cleaning installation is shown in Figure 2. We find many developments in the methods and equipment used in regulating gas pressure. The Reynolds control has been the forerunner of a large number of pilot regulators and combinations of pilot controls. Figure 3 shows an automatic hookup which is almost the n'th degree of pilot control. The regulator companies have developed pilot controls with varying characteristics and degrees of sensitivity to meet particular requirements. Auxiliary pilots will accomplish wonderful things when the installation is correctly designed by a competent engineer. A number of instrument companies have on the market regulator controllers. These instruments may be obtained to give very close control of outlet pressure regardless of variation in inlet pressure or variation in load. They may also be obtained to give an outlet pressure which varies at different times of the day and is controlled by a clock operated cam, which may be cut to give the desired results. One of these instruments is shown in Figure 4.

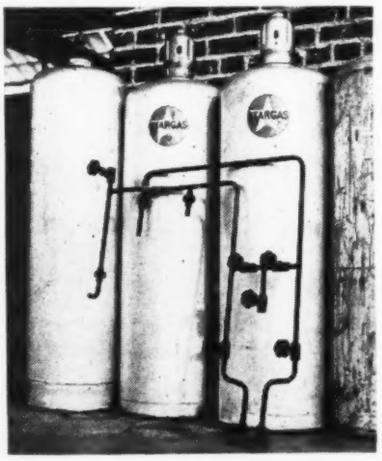

Figure 1. Welded Meter Piping

For years gas engineers have wanted a satisfactory method of obtaining increased outlet pressure during times of increased demand. At first the very small valve travel which actually occurs in the operation of the regulator seemed to present a mechanical difficulty in designing a pressure booster. This difficulty has been overcome by utilizing the increased impact resulting from increased loads and satisfactory pressure boosters can now be obtained. An unforeseen difficulty arose from their use in distribution plants. Where a number of regulators feed into a large distribution system and pressure boosters are used it is found that the first booster regulator to catch an increased load will tend to deliver an increased outlet pressure which will back up on the other regulators feeding the system and tend to shut them down, thus tending to make the first regulator hog the load, resulting in too high a pressure being carried in the line adjacent to the first regulator. This tendency must always be considered in planning on the use of pressure boosters.

At city gate measuring stations the regulators often freeze up, due to expansion of the gas and heaters are often installed ahead of city gate stations similar to the heaters installed near high pressure wells. This is expensive and also entails considerable hazard. It has been found that where a large pressure cut through one regulator results in freezing, the division of this pressure cut between two or three regulators in series will give satisfactory operation without freezing. It has been found advisable to install a volume or cushion between these regulators. The cushions perform the dual function of assisting in the reduction of freezing and also in reducing the tendency to pump. The reduction in shutoffs caused by freezing, the saving in the cost and expense of operation of heaters and the reduction in the general maintenance cost of multiple regulators in series very well justify their additional cost. Figure 5 shows a balloon or cushion header between high and semi-high pressure regulators. Incidentally, it is found that the extreme sensitivity of a pilot regulator in conjunction with the limited volume between regulators usually makes it impracticable to use a pilot operated

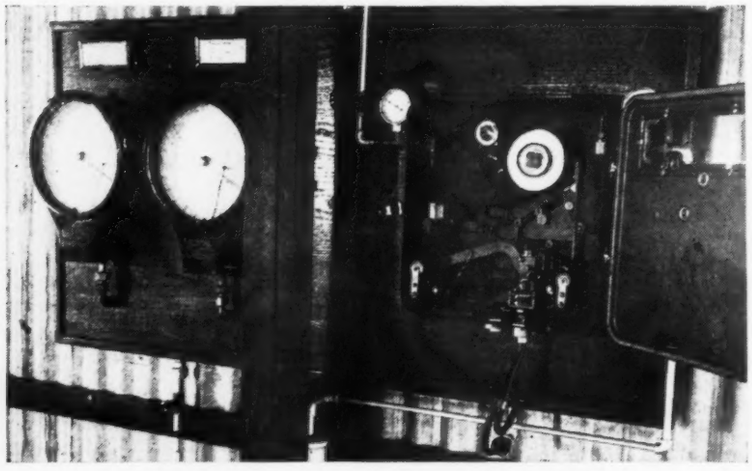

Fig. 4. Pressure Time Controller at Border Station

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regulator for any except the last of such a series of regulators.

The wide range meter or the combination of 100″ and 20″ differential recorders connected to the same orifice are now in general use. Several equipment companies have developed differential limit controllers for automatically cutting in and out additional meter lines when required that are exceedingly dependable and satisfactory. These instruments provide a power step-up which furnishes more than enough power to provide a full opening or a positive shut-off to the valve to which they are connected.

For many years large capacity meters were often set and not tested for long periods of time, or, if tested at all, were tested at very low rates of flow. Now these meters are tested by the use of large capacity aluminum test meters, low pressure orifice provers or critical flow orifice provers. The critical flow prover has been particularly valuable in testing large capacity positive meters at the high pressure and at the rate at which they are actually operating. Much larger high pressure positive meters have been built during the last few years and the design and materials used have been greatly improved. Two instruments are on the market for correcting the index reading for working pressure to the contract pressure base. In both instruments the revolutions of the meter operate in the instrument. Both have also been found to check out very closely with hand read charts and, where there is a difference, the probability is that the instrument is more accurate than the hand reading.

Orifice meters themselves have been steadily improved until those now manufactured are very satisfactory and give a minimum of trouble. One of the most spectacular developments is the integrating orifice meter recently announced by one of the meter companies. This instrument is provided with an index which reads directly in total extensions and it is only necessary to multiply the difference between extensions by the coefficient to determine the quantity of gas for any period of time. The mechanism of this meter is operated by either a Telechron clock or a gas operated clock. The differential and static operate pointers along cylindrical cams in an ingenuous hookup, which results in the multiplication of time, the square root of the differential, and the square root of the absolute static, thus giving the total extension as the result.

We have followed our developments from the sand at the bottom of the well through to the final regulation and measurement. The development of the chart integrator has been exceedingly valuable to the office end of our business. This integrator is a great saver of time and expense and is generally conceded to be more accurate than hand reading.

The development of the technology of orifice meter measurement has been greatly furthered during the last five years by the gas measurement committee of the Natural Gas Department of the American Gas Association. Gas Measurement Committee Report No. 1 has been available for some time. This report treats of the committee's recommendations as to meter fittings and installations, diameter ratio limitation, and operating conditions, coefficients and compressibility. The five years' work of this committee has greatly strengthened the industry's confidence in the coefficients we have been using for many years. The great volume of data accumulated by this committee is being correlated with the work by the Bureau of Standards and the American Society of Mechanical Engineers for the purpose of getting out jointly a final report. With such a background and sponsorship this final report should certainly be taken as authentic for many years to come. The Committee Report No. 1 may be obtained from the American Gas Association office at 420 Lexington Avenue. New York, or 714 Dallas Gas Building, Dallas, Texas.

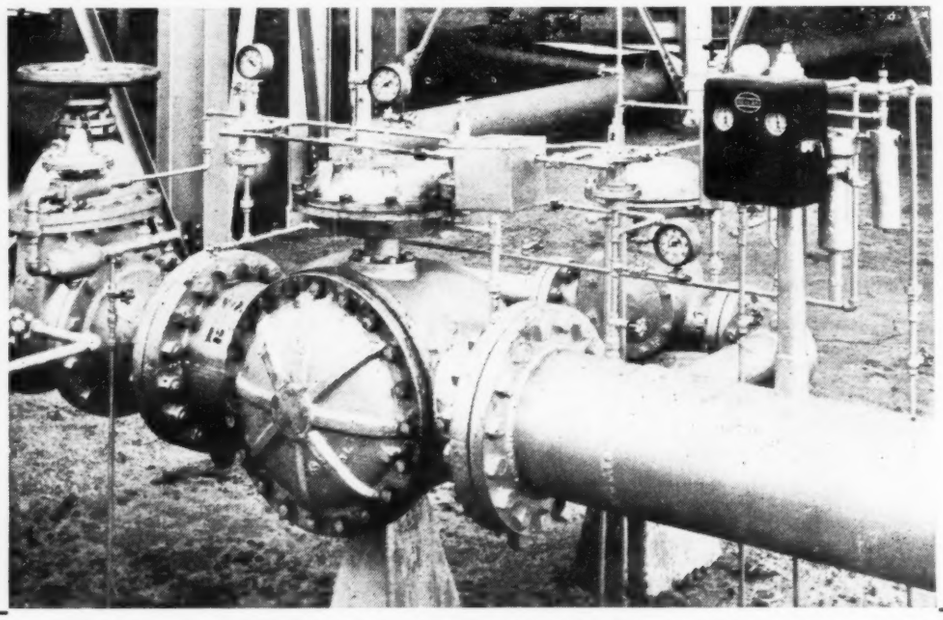


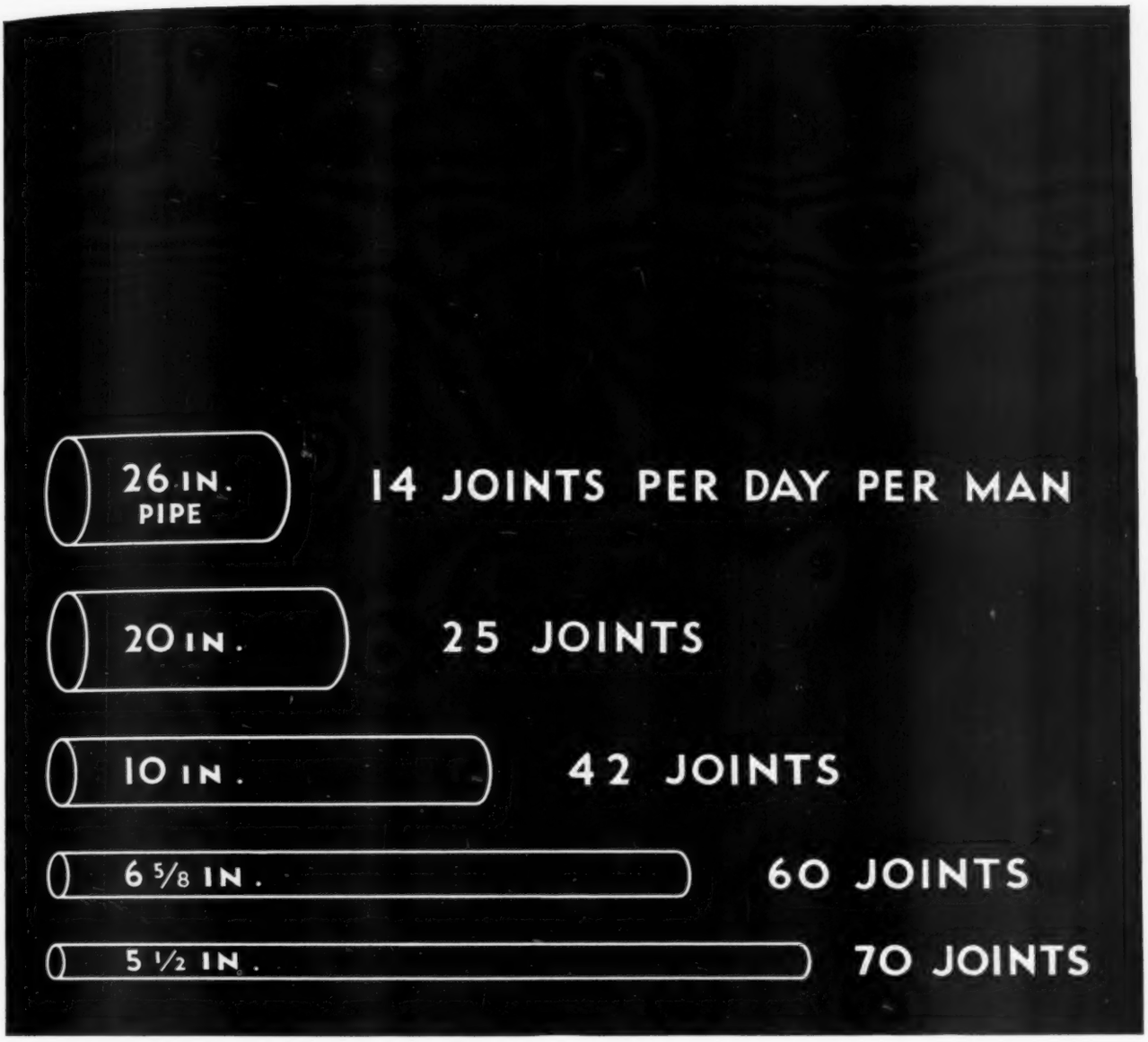
Figure 3. Distribution Regulation and Automatic Controls (An Explanation of its Operation Appears Below)

The distribution regulator and booster set-up provides for the automatic boosting of the distribution pressure when the load reaches a certain value.

The two central pilots feed gas from the holder line to the head of the regulator. The pilot nearest the differential switch, set at four pounds per square inch, is cut in and out of service by the electric valve which is controlled by a time clock. This clock cuts in the pilot set at four pounds at certain hours of the day when the minimum pressure necessary is that amount. During the night and off-peak periods, this pilot is out of service, so that the other pilot, which is set at three pounds, maintains the distribution system.

The operation of the booster is as follows: The Neilan Differential Switch is connected across an orifice located on the downstream side of the regulator. When the differential across this orifice exceeds a certain pre-determined value, the differential switch operates, shutting off the supply of pressure to the control line of the Booster Pilot. The pressure trapped under the lower diaphragm of the pilot then bleeds out to atmosphere through the mechanism in the differential switch. The removal of this pressure allows the Booster Pilot to open and feed gas to the head of the regulator, raising the distribution pressure to five pounds per square inch. When the distribution load drops off, and the differential returns to normal, the differential switch applies pressure to the control line of the Booster Pilot, cutting it out of service. The regulator pressure then drops down to either three pounds or four pounds per square inch, depending on whether the electric valve is opened or closed.

(Courtesy of F. A. Hough, Engineer, Southern Counties Gas Co., Los Angeles, Calif.)



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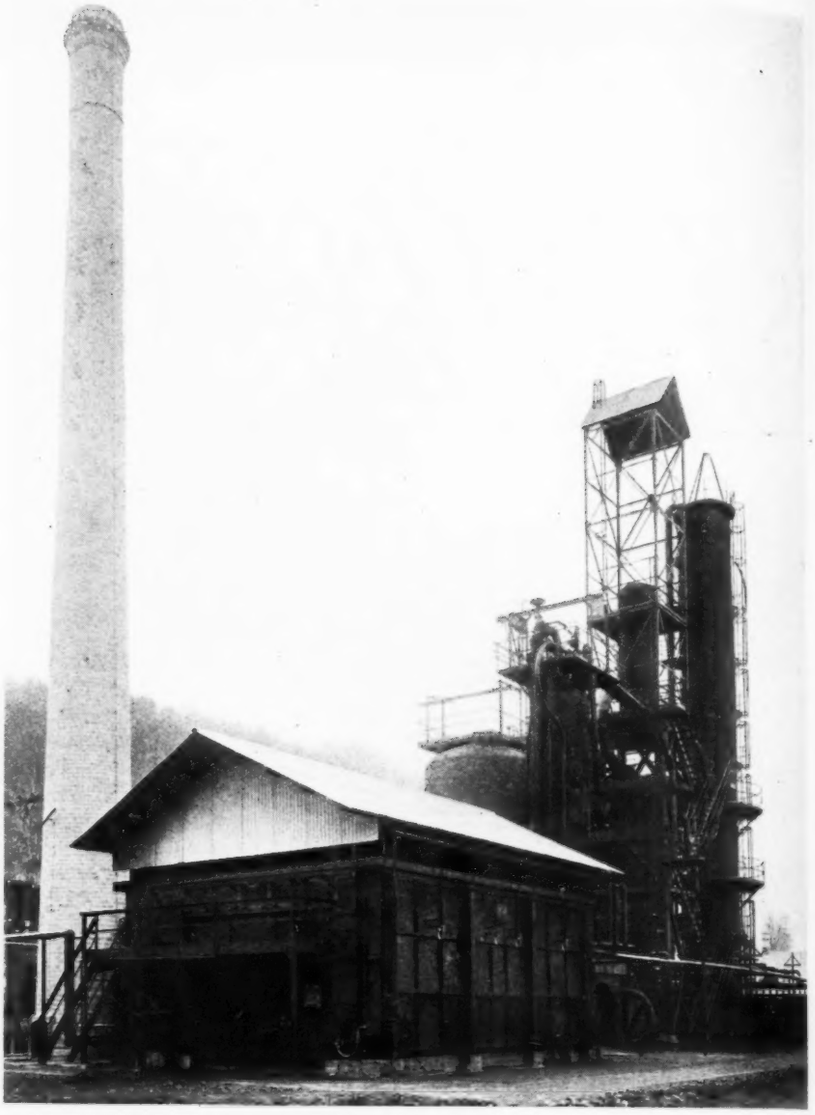
Progress in Refinery Furnace Design

By A. E. NASH☆



Alcorn furnace on Dubbs cracking unit of the Kendall refinery

THE modern furnace now in use in connection with various processes in the refineries is primarily a development of the last half dozen years. Prior to that time a furnace was frequently nothing more than a chamber or space provided to burn the necessary fuel, in connection with some form of heat absorbing structure, such as tubes or shell bottom. After introducing the fuel and air into this chamber the hot gases and products of combustion were directed against and made to "wash" the heating surface.

Several limitations were encountered and certain generally accepted conditions were commonly recognized as necessary for successful furnace operation. Particularly in the case of cracking coils it was found that high temperature gases meant trouble, and those tubes which were exposed to the heat radiated from the roof or side walls, and at the same time were in contact with the hot gases, had to be watched very carefully. Since those tubes which were not exposed to wall radiation seldom failed, radiant heat was promptly condemned and was avoided wherever possible. Since high furnace temperatures necessarily meant incandescent furnace walls radiating directly to only a few of the tubes, such temperatures had to be avoided.

Attempts to lessen this radiation by the use of "Dutch Ovens" were only partially successful, and the general practice was to introduce large quantities of excess (cold) air. This practice automatically resulted in very low furnace efficiencies and later the recirculation method, which decreased the temperature of the gases by forcing a part of the waste stack gases back into the furnace, was developed. By this means the furnace efficiencies were raised and at the same time the increased volume of gases resulting tended to improve the transfer of heat by convection.

As late as 1926, most plant operators would not approve of furnace temperatures in excess of 1500 degrees F., while the idea of generally utilizing radiant heat was ridiculed. Under such conditions only relatively low rates of heat input were possible, and the industry as a whole was convinced that high heat transfer rates were dangerous. To meet this situation and to satisfy the refiners generally, furnace designers were forced to so proportion their units that no temperatures of more than 1500 degrees F. would result, and no tubes received heat at a rate greater than about 5000 B. T. U. per square foot of extended surface.

As early as 1923, the Alcorn Combustion Company, recognizing the limitations and difficulties of these methods of transferring heat to the oil, started to investigate the possibilities of utilizing radiant heat. A study of various existing furnaces at once brought out certain definite sources of trouble. Secondary combustion, resulting from imperfect mixing of the fuel and air under proper combustion conditions, the difficulty of controlling and evenly distributing the hot gases, the necessity for the first two or three rows of tubes to take up several times as much heat as other tubes, were only a few of the objections. First costs, due to the large number of tubes required, were excessive, while the quantities of excess air used to reduce gas temperatures made good furnace efficiencies impossible. On the other hand, at operating temperatures the rate of heat transfer as radiant heat was many times that possible by convection at similar temperatures. At the same time, given a controlled source of radiant heat, such heat could be evenly and easily distributed over large areas. This would permit of furnace designs using far less tubes and make possible furnaces of very much greater capacities.

A further study indicated that the difficulties generally charged against radiant heat were primarily due to uneven heat distribution, particularly where tubes were exposed to

☆ Alcorn Combustion Company.

direct radiation from the settings and at the same time were in contact with the hottest gases. Frequently, too, such tubes were also subjected to secondary combustion—the incompletely burned gases burning directly in the tube bank. It was discovered that most of these difficulties could be entirely overcome simply by separating the radiant from the convection heat, and so designing the furnace that certain of the tubes received heat almost solely by heat radiated either from refractories or by direct radiation from the hot gases, while other tubes, so located that they were not "in sight" of such radiating surfaces, were heated by (convection) direct contact with the hot gases. Such a design at once made possible higher furnace temperatures since the section evenly heated by radiant heat removed a considerable portion of the excess heat and reduced the temperature of the hot gases to any desired point. Complete separation of the radiant from convection heat was unnecessary since, while there is always some transfer by radiation in the convection section, the rate of transfer by radiation at these reduced temperatures is very low and the small amount of heat transferred by convection in the radiant section can be disregarded.

A substantial separation of the radiant from the convection heat could be secured in various ways and each method had certain advantages. The burning fuel could be "screened" from the "radiant" tubes by interposing materials which would radiate heat but which in general would prevent the passage of the hot gases, or the furnace could be so designed that the natural flow of the gases would keep them away and out of direct contact with certain tubes.

The use of firing tunnels with a restricted cross section was known, and the advantages of such a construction from the combustion standpoint was well recognized. Complete mixing of the fuel and air at high temperatures was assured and direct contact between the tubes and the hot gases prevented. However, such firing chambers when constructed of ordinary refractories, develop such high temperatures within the chambers that they are destroyed in a few hours under hard firing. Carborundum, on the other hand, having a high factor of heat conductivity, permits a considerable part of the heat generated to radiate from the outside of the chamber, thus reducing the temperature of the gases. At the same time, carborundum itself will withstand temperatures considerably higher than other refractories, and firing chambers constructed of carborundum brick or tile will usually last for a sufficient length of time to justify their use. If, therefore, a furnace was fired through carborundum firing chambers, almost perfect combustion conditions were assured, and this construction offered a means of locating certain tubes so that they would be heated almost solely by heat radiated from the surface of the carborundum muffles.

By properly proportioning the areas of carborundum radiating surface with the amount of fuel fired, the temperature of the gases leaving the carborundum firing chambers could be fairly well regulated. Since plant operation at that time insisted on keeping the gas temperature below 1500 degrees F. rather long carborundum muffles were required to provide the necessary radiating surface. Furnaces designed on this basis proved entirely practical and although the cost of the carborundum was considerable, the improved furnace operation more than justified the expense. In consequence, some thirty or more furnaces were constructed along these ideas and proved conclusively their advantage over other types of furnaces then in use. Nevertheless, considerable objection was raised to the cost of maintenance, due to the large amount of carborundum required, and efforts were made to reduce these costs.

The operation of these furnaces proved conclusively that much higher rates of heat transfer were not only practical but desirable, when the even heat distribution possible through the proper application of radiant heat was obtained. At the same time it was found that if tubes were subjected only to heat by convection from the hot gases, and such gases were properly distributed, temperatures of over 1500 degrees F. could be used with safety. With these facts in mind a furnace was designed taking advantage of firing through a number of carborundum muffles, but materially reducing the amount of carborundum required by shortening the length of these muffles. The temperature of the gases leaving these muffles was considerably higher than in the case of the longer carborundum chambers, but this feature was taken care of by locating other tubes adjacent to, but out of the path of, the hot gases until these gases had lost sufficient heat by radiation and dropped in temperature to the desired point. Since tubes so located received their heat almost solely by radiation they could by proper designing be arranged to insure very even heating, and consequently were selected to carry the oil at the higher temperature.

Two furnaces were soon built on this design and they at once proved their worth. Very high furnace efficiencies were secured and the operation was greatly simplified. The heat distribution was such that very high rates of heat transfer (of the order of 15,000 B. T. U. per square foot) were possible and at the same time higher transfer temperatures could be obtained. A larger furnace of this type was then designed and built, taking advantage of the various points which had been conclusively proven. The high average rates of heat transfer permitted the number of tubes to be greatly reduced, effecting a saving in first cost and materially reducing the time required for cleaning the tubes as well as the cost of pumping, since the coil drop was considerably lessened.

While proper furnace design and operation does not by any means insure the success of any process, since many other factors are present, there is no question but that such operation materially simplifies the operator's problems. Poor furnace design and conditions undoubtedly are responsible for many plant difficulties, while good furnace conditions, with properly designed tube arrangement and oil flow, permit of greater latitude in controlling the process and may be a considerable factor in better yields, greater thruput, higher octane and superior products. Modern motors demand better grades of gasoline, and refiners realize that higher octane values usually may be secured by higher transfer temperatures. To permit such temperatures absolutely even heating is essential, since the margin of safety in the metal temperature of the tubes is correspondingly lessened. Uneven or spotty heating results in local overcracking, with heavy coke depositions, tube failure and excessive gas loss. Tubes heated almost solely by radiant heat offer one of the best and safest means of obtaining these high transfer temperatures, and furnaces so designed permit of much greater thruputs per unit of tube area.

Before building a furnace for any particular process today the refiner should look carefully, not only at the process requirements at this time, but also to the probable trend of public demand and the consequent changes in operation which may be necessary to meet this demand. The furnace design should be such that perfect combustion of the fuel is assured with no possibility of secondary combustion. All the tubes should do their share of the work, with no idle tubes. This means a high general average with no tubes operating under dangerous conditions, and is only possible with even heat distribution. If required, the furnace should be capable of handling high transfer rates safely, to accomplish which it is essential that the tubes carrying the hottest oil should not be subjected to contact with high temperature gases and the consequent danger of local overheating. Excessive size should be avoided, since this means greater first cost, more maintenance expense, and requires greater valuable ground space. Too many tubes also mean an excessive pressure drop through the coil, requiring more expensive pumping equipment and more power for pump operation. The furnace best adapted to modern refinery practice should be simple and compact, flexible and safe, easy of operation and control, and should be designed to meet the requirements of tomorrow where possible.

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Trends in Design of Production Equipment in California

By J. H. WALLACE, JR.☆

THE developments of the last six months have been very largely dictated by the extreme necessity for economy. Low selling price for equipment is as necessary as low operating cost.

In line with this general attitude of economy designers of production equipment have applied themselves to producing efficient models at lower cost. This has necessitated the elimination of surplus material and unnecessary mechanical parts. Along this line the motorized reduction gear is coming into prominence.

The most outstanding development in pumping power is the radically new pumping unit known colloquially as the "Motorized Counterbalance." This unit, shown in Figure 1,

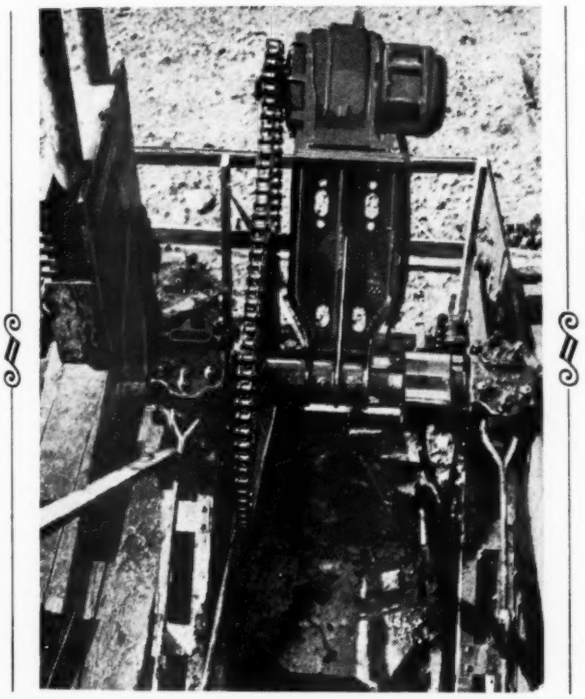

Fig. 1. Twenty-horsepower motorized counterbalance unit

utilizes the weight of the motor, gear, and attendant castings as a counterbalance. The principle involved is extremely simple and can be seen by observing the illustration. A motorized reduction gear is mounted on a cast steel bracket secured on the bandwheel shaft in line with the pitman crank. The low speed shaft of the gear is connected by a chain to a large stationary sprocket concentric with the bandwheel shaft. The cast-steel bracket is fitted to receive a large number of counterweights, thus converting the unit into a rotary counterbalance capable of balancing the heaviest of wells. This unit symbolizes the modern trend in design; compact, efficient, unit construction.

These units are built in sizes from one to 25 horsepower with speeds ranging from three strokes per minute to 30 strokes per minute. The smaller sizes of course, being used for slow speed pumping of small wells.

☆ Stoody Company, Long Beach, Calif.

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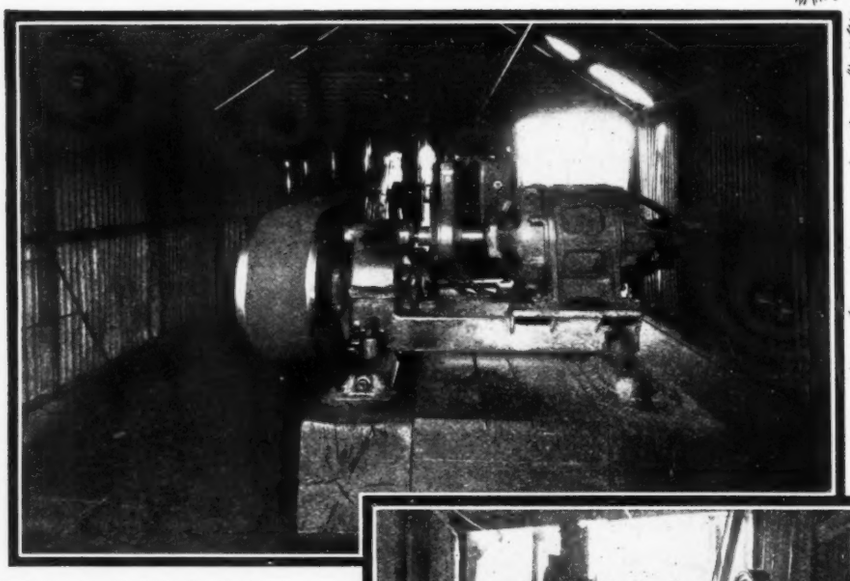
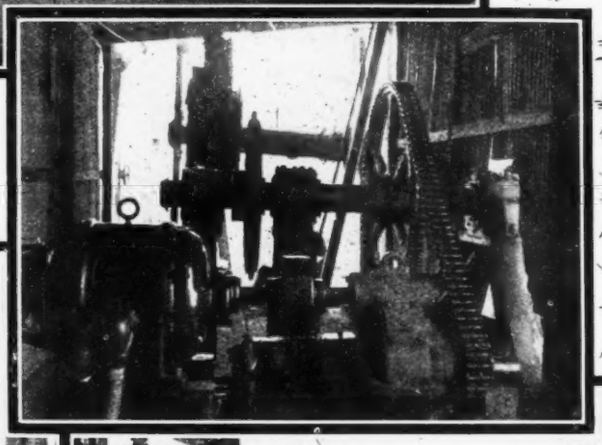
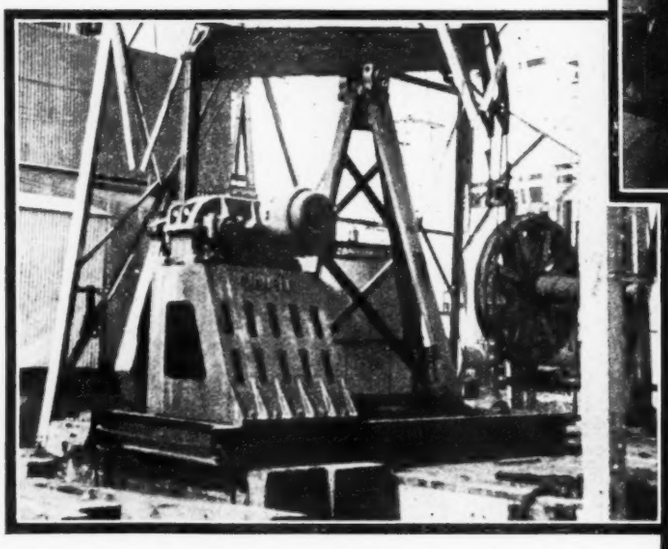
BEFORE FLOWING WELLS

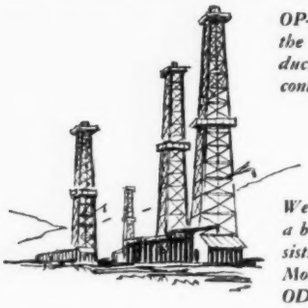


Westinghouse electric pumping outfit on a standard rig in Arkansas —2-speed Oil Field Motor, unit control and OP Single Reduction Gear.



Westinghouse electric drive for rig fronts, consisting of 2-speed Oil Field Motor, Unit Control, and OP Single Reduction Gear. Motors and Control may be either open or gas-protected types.





OP-300 Unit Pumping Power installed in the Venice field. Motor, Starter, and Reduction Gears are combined into a self-contained, weather-proof unit.

Westinghouse slow-speed electric drive on a beam well in California. The drive consists of a Linestart Squirrel Cage Induction Motor connected through V-belt to an ODH Gear.

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For this purpose ODH unit pumping powers are, without exception, the simplest and most economical to install and operate. Pumping speeds as low as one stroke per minute are obtainable.

For beam wells also, slow-speed drives, consisting of ODH reduction gear and motor are available for any pumping condition or arrangement.

FOR HEAVY PRODUCERS

Heavy producers require pumping equipment with sufficient power and mechanical strength to lift large volumes and to overcome high friction and inertia loads. For this service, Westinghouse offers two-speed oil field motors and type OP reduction gears. Besides pumping, these drives also are capable of performing all cleaning and pulling operations.

For beam wells, the new OP-9 heavy-duty single reduction gear provides a direct drive, with either a two-speed motor or a gas engine. A power take-off is provided for driving the production hoist.

For pumping service only, OP-300 unit pumping powers are sturdy, self-contained, weather-proof outfits that keep lifting costs down. The unit-built drive of these pumping powers may be applied separately on beam wells.

WHEN PUMPING SPEEDS MUST BE CHANGED

All of these electric pumping drives for light and heavy producers permit an easy change of speed over a wide range. This flexibility assures the most efficient recovery of oil at minimum operating costs regardless of changing production allowables or changing well conditions.

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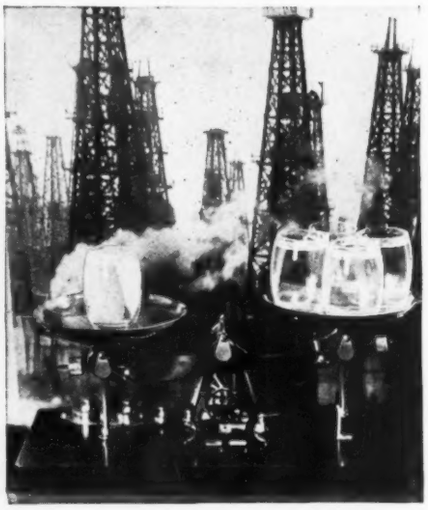

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Another unit of much merit is the so-called "Torque Arm" drive. This unit is supported by bearings on the bandwheel shaft between the jackposts. Like the "Motorized Counterbalance" this design also utilizes existent standard end equipment for foundation. The motor is connected to a single reduction gear by a multiple "V" belt drive, the slow-speed gear shaft is chain connected to a large sprocket fixed to the bandwheel shaft. The outer end of the power framework is supported between two heavy springs on a steel framework. The unit is prevented from rotating by the supporting springs and framework. The springs are intended to absorb the shock due to sudden torque changes, hence the name "Torque Arm" drive.

This unit was first constructed for slow speed pumping of small wells but has been found admirably adapted to the production of the heaviest wells.

These units are equipped with an ingenious device known as the "Torque Switch." This switch was devised by C. L. Moore of the Chanslor-Canfield Midway Oil Company. Moore utilized the movement of the torque arm between the supporting springs to operate a Mercoid switch and thus provide a most excellent safety device. The motion of the torque arm in one direction is the resultant of the lifting (positive) torque, while the reverse motion results from the overriding (negative) torque. The Mercoid switch is operated by a small lever which is supported between two set screws on the torque arm. The screws are adjusted to allow for all movement of the torque arm due to normal operating conditions. An excessive torque in either direction will cause correspondingly greater movement of the torque arm and throw the switch, thus shutting off the motor. Should the well sand up, therefore, the additional torque will immediately shut off the motor, preventing damage to the equipment; broken rods, pitman, or hanger will immediately result in an excessive torque in the opposite direction likewise shutting down the well.

The torque switch fills a real need in slow speed pumping where the torque at the motor, due to the very low speeds sometimes used, is frequently sufficient to cause considerable damage before the thermal overload relay operates. It should be remembered, however, that the torque switch is an auxiliary and should by no means supplant the thermal relay.

Considerable attention is still being given to slow-speed pumping in California. Recent developments have been in

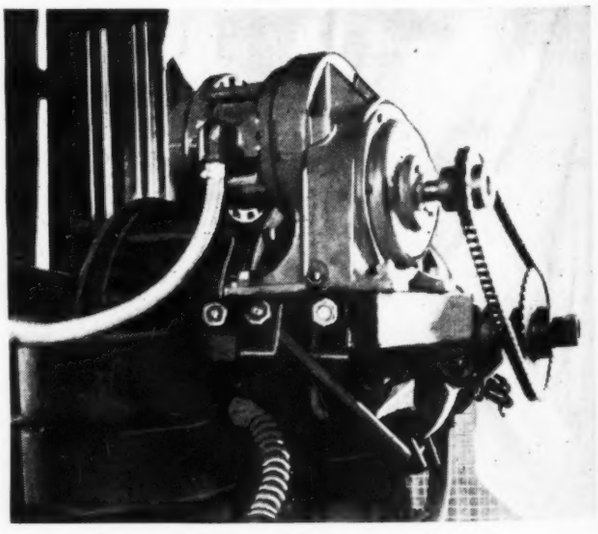


Fig. 2. Three-horsepower motorized gear driving 15-35 H.P. oil well motor

the nature of improvements on existing methods. The motorized reduction gear is gaining rapidly in popularity as a glance at the recent installations will indicate.

Slow speed pumping drives may be divided into three general classes:

First, those that drive through the existing prime mover. Everyone is familiar with the type of drive utilizing the standard engine as a jack shaft. Figure 2 shows a new installation using a motorized gear and small motor to drive a 15-35 horsepower slip ring motor. The larger motor is used for pulling, while the slow speed is economically obtained by the small motor-gear unit.

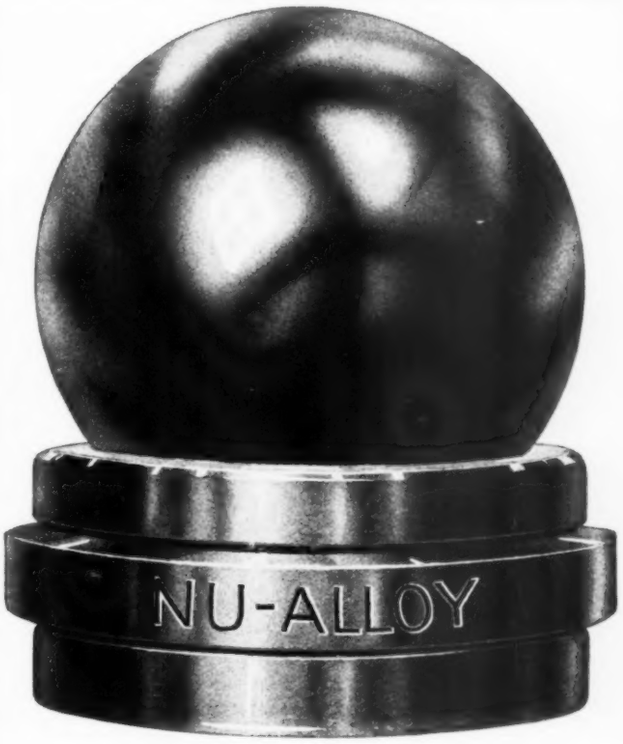
Second, those drives connected directly to the bandwheel shaft. Figure 3 shows a compact drive of this type using the popular motorized gear and a small countershaft mounted on the same base. The two units first mentioned in this article are both examples of this class of drive.

Third, those units that are entirely independent of all existing equipment, namely floor jacks. Everyone is familiar with the many different units of this type available. One manufacturer has utilized the bed of a standard steam engine to reduce manufacturing costs. This jack is one of the cheapest pieces of equipment on the market and is at the same time remarkably efficient and compact. It might well be called the "Depression Model."

Variable speed drives have long been the dream of every manufacturer as well as the engineer, but little seems to have been accomplished. The increased demand for such equipment for slow-speed pumping and the small power required have brought forth several designs. In one drive of this type. the driven pulley is composed of two cone-shaped parts held together by a spring, and the motor pulley is solid. A "V" belt connects the two pulleys. The motor is moved back and forth on the base by means of a screw control, thus changing the distance between centers of the pulleys. The spring on the driven pulley maintains a constant pressure on the belt. as the center distances are changed the "V" belt rides either higher or lower in the driven pulley, as the case may be, thus changing its effective size. Ratio changes of five to one and ten to one are obtainable by this device. These drives are built up to 10 horsepower. They are not only inexpensive but remarkably efficient and compact. It is believed they will occupy a place of importance in the future development of equipment.

A change in design in the well-known Pitman counterbalance marks the only thing new in the line of counterbalances. Two widely separated pitman rods replace the conventional single "I" beam. This change remedied one of the weak features of this type of balance. When used on heavy wells the whip of the weights caused continual breakage of the single pitman member. The double connection link provides a moment of inertia sufficiently great to withstand these strains.

The pump manufacturers have been busy with the problems presented by the high pressures and heavy pump loads resulting from the great depths encountered in California wells. The insert pump with its accessibility has been exclusively used. The extreme high unit pressures and temperatures encountered at 5,000 to 7,000 feet causes such contact pressures between the cup and the barrel that pump life is very short. The liner type pump with its rigid barrel and all metal plunger is admirably suited to answer these troublesome problems, but the loss of capacity due to the space required for the liners has seemed to exclude them from the insert class. Offsetting this, however, was the necessity for keeping the rod loads within workable limits, namely, through the



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use of smaller diameter pumps. These two factors have worked together very nicely to bring about the design of the liner insert pump. This type of pump is now the recognized equipment for deep well production.

Little change in rods has been made for deep pumping. The smaller effective diameter of the pumps used reduces the loading to such a point that the present rods are sufficient. The ¾-inch rod is still the most popular, largely due to the small oil strings used at the lower depths. Some operators are using combination strings of ¾-inch and ⅞-inch rods. The use of large rods is undoubtedly desirable where the size of hole permits. One point that seems to have been entirely overlooked in the study of rods is the effect of rod stretch on very long strings. Rods are designed primarily for strength, the box and pin being made equal to the rod in strength. Some day someone will try a string of rods, using rods of the full box diameter. If one is mathematically inclined a study of the stresses and elongations in the two types of rods will prove of interest. It is believed that the use of large diameter rods, long, slow pumping strokes will reveal pumping economies, at the greatest depths, and will far offset the additional cost. The additional amount of balancing required is not a serious item.

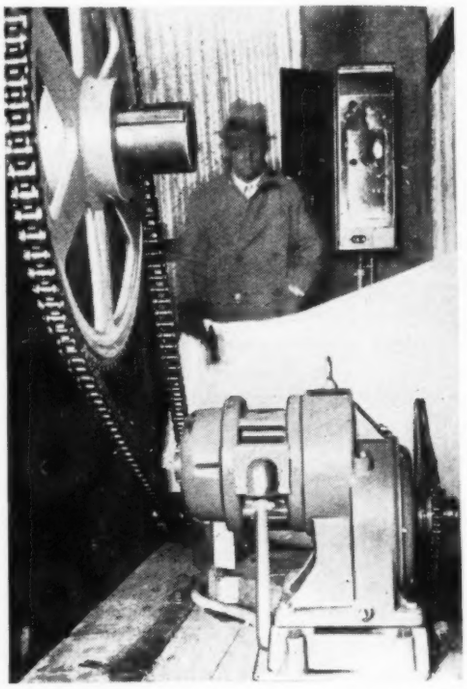


Fig. 3. Three-horsepower motorized gear driving band-wheel shaft

The development of the electric motor for pumping is temporarily at a standstill. The equipment manufacturers are, however, doing some work along this line. The desirability of the high slip, high torque motor to reduce peak loads and thus enable the use of smaller motors for specific jobs is entirely underrated. Recent tests were conducted by one of the leading motor manufacturers on normal and high slip motors. That these tests failed to bring to light the value of the high slip motor was due to the fact that the installation was entirely over-powered in the test. The advantage of the high slip motor is only apparent when the motor is sufficiently loaded to utilize the slip. It must be remembered that the no-load speed will be the same for both types of motors, the amount of slip being directly proportional to the loading.

Modernizing Refineries to Meet New Vapor Pressure Specifications

By C. A. RUSSELL☆

WHENEVER specifications of petroleum products are changed it is necessary for refineries to revamp their equipment in order to comply with the new specifications. Sometimes the revamping is done before the specifications are changed, in order to anticipate the change in market or to increase the marketing value of the finished product. In any case, however, whether the change is made voluntarily by the refiner or after the new specifications have been announced, a certain amount of remodeling is necessary. The government has announced that on October 21st, 1932, a new set of specifications for motor fuel will become effective. These new specifications are automatically adopted by many states which accept the government recommendations without question. In other states these specifications will be adopted sooner or later by specific legislation.

The principal interest in the new specifications centers in the requirement that the vapor pressure of motor fuel shall not exceed twelve pounds per square inch at a temperature of 100 degrees F. and at the normal barometric pressure at the point of delivery. In the tropical regions the vapor pressure must not exceed eight pounds per square inch under the same conditions. These new rulings will affect practically every refiner, especially on account of the constantly increasing proportion of cracked gasoline with its larger percentages of volatile fractions. Many refineries would be forced to adopt some means of decreasing the vapor pressure of the finished gasoline, because of the increased use of cracked gasoline, even though the government had not issued new specifications.

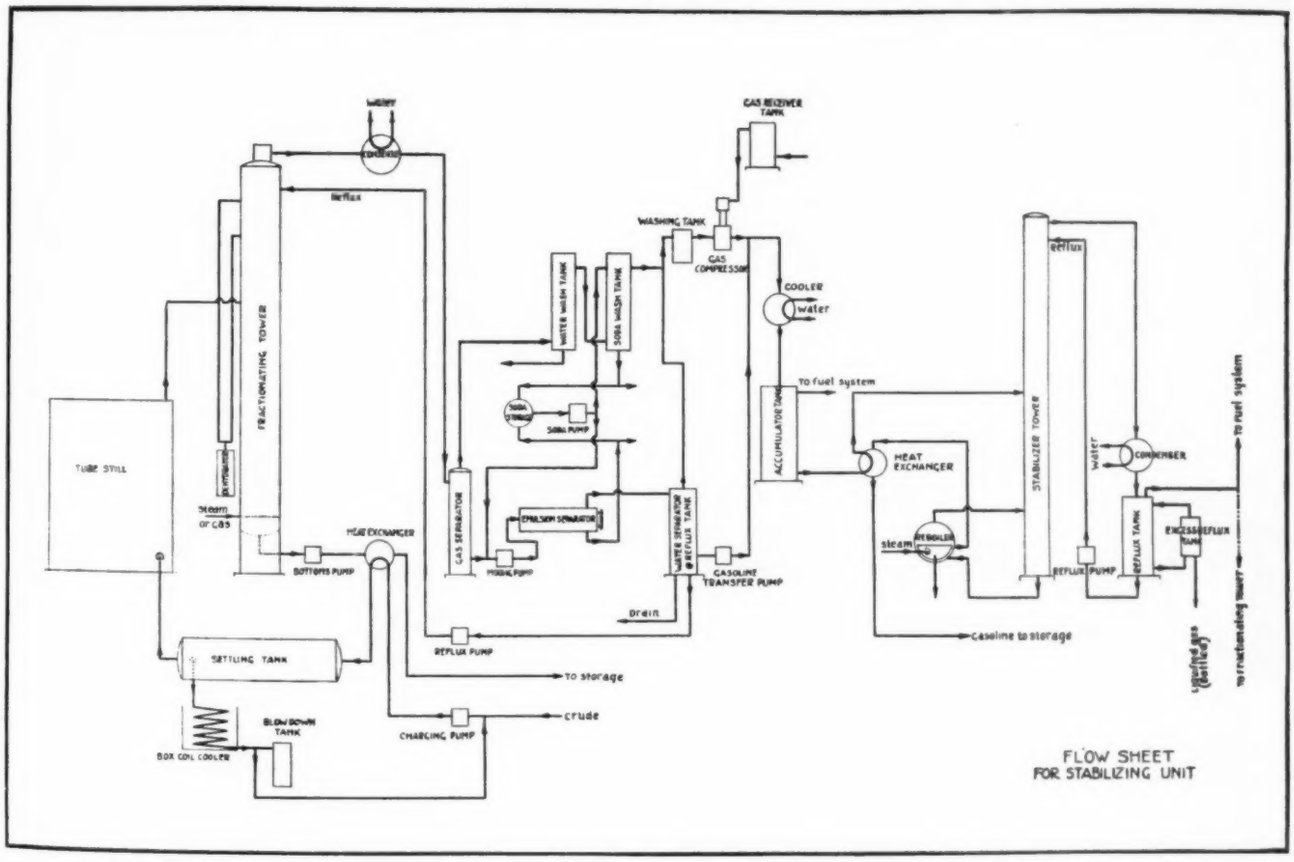
Vapor pressure of finished gasoline is dependent upon several factors, all of which must be compensated for if complete control is to be obtained. Inasmuch as some change is necessary it is generally most economical to install equipment which will effect complete control of the entire cycle. The simplest equipment to obtain this end is a crude stabilizing unit. The elements which generally cause high vapor pressure in gasoline are hydrogen sulphide, and hydrocarbon gases including the lighter gasoline fractions. Most of these elements can be liberated from the crude at relatively low temperatures under the operating pressure required for condensing the recoverable products.

By removing from the crude those undesirable constituents mentioned above, material savings will be effected throughout the various refining processes. Complete control of the entire refinery operation is obtained by prestabilization of the crude before fractionating it in the regular distillation units. Seven major economies derived from prestabilization of crude are as follows:

1. Water, water soluble salts, and sediment are removed from the crude.

2. Corrosive gases, such as H_2S are removed from the crude before it is sent to storage, thus increasing the life of storage tanks and reducing maintenance on them. Removal of

☆ Foster Wheeler Corporation.



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corrosive gases also reduces the amount of corrosion in untreated straight run gasoline and kerosene storage tanks and in the piping to those tanks. Most of the corrosion in the distillation unit is avoided on the two top streams where it is greatest.

3. The treating costs for straight run gasoline and gas is materially reduced by prestabilizing of the crude.

4. Removal of the lighter gasoline fractions effects a large reduction in the piping costs for recovery from the crude and gasoline storage tanks.

5. Elimination of the lighter products also reduces the vapor losses from the gasoline storage tanks.

6. The fire risk of storage tanks is reduced by removal of the lighter fractions previous to storage.

7. Prestabilizing permits better control of the vapor pressure and distillation curves for the finished gasoline. The distillation range of the new standards call for:

10% at 167 degrees F.
50% at 284 degrees F.
90 at 392 degrees F.

The new specifications also require that the residue shall not exceed 2 per cent.

It can thus be seen that prestabilization of the crude is an absolute necessity if complete control is to be obtained, especially over such crudes as East Texas with which so much trouble is experienced due to gas.

One Seaboard refinery has installed a complete crude stabilization unit which operates according to the scheme shown in the accompanying diagram. The unit is divided into three parts, a crude fractionating unit for the vaporization of the light fractions, a complete settling and washing equipment for the removal of sediment, soluble salts and acids; and a stabilizing unit for the recovery of light gasoline fractions to be used in blending.

Crude oil is taken from storage tanks and is pumped at a pressure of 215 lbs. per square inch through a series of six shell and tube type heat exchangers where it recovers heat from the stabilized crude. The temperature is raised from 68 degrees F. to 230 degrees F. The crude is then discharged into three cylindrical settling tanks which have sufficient capacity to hold the crude oil for forty-five minutes. The crude in the tanks is under a pressure of 200 lbs. per sq. in. The water, salts and other foreign solid matter contained in the charge will be settled out in these tanks before the crude oil flows into the tube still. These tanks are insulated so that when the crude reaches the still it contains practically all the heat received in the heat exchangers.

The tube still raises the temperature of the oil to 280 degrees F., at which temperature it is discharged to the fractionating tower about two-thirds of the way up from the bottom. The fractionating tower operates under a pressure of 40 lb. per sq. in. Vapors rise through the tower and the liquid flows to the bottom. On the way down through the series of bubble trays the crude is stripped of the lighter fractions by vapor which is admitted to the tower at the bottom. This vapor may be either non-condensable gases from the gas stabilizing plant or exhaust steam, depending upon which is desired for operation. The crude is taken from the bottom of the tower by pumps and discharged through the crude heat exchangers mentioned above. This crude is completely stabilized, and free of water, sediment, and salts. It is cooled by the heat exchangers from an entering temperature of 270 degrees F. to an exit temperature of 100 degrees. From the heat exchangers it flows to rundown or storage tanks.

The light gasoline vapor and the stripping gases pass up through the fractionating tower and thence into shell and

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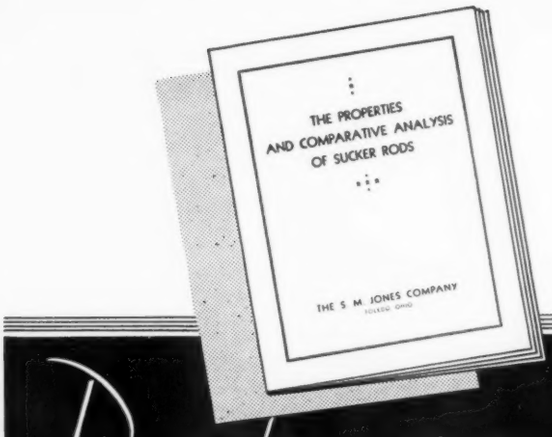

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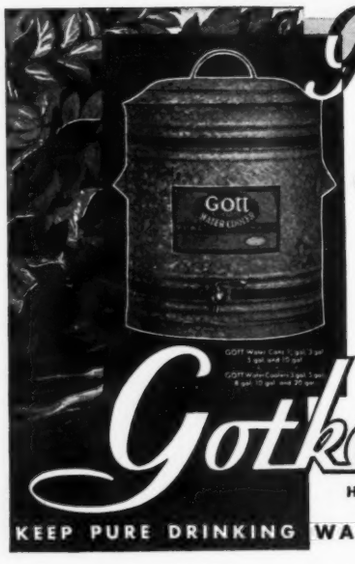

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tube type condensers where some of the gas is condensed and the condensate and vapors are cooled to 70 degrees F. The condensers operate at approximately the same pressure as the tower so that a considerable portion of the overhead is liquified. The condensers discharge to a vertical tank in which the permanent gases and liquid are separated. The permanent gases obtained by vaporization are automatically released to control the pressure within the separator and thus within the condensers and fractionating tower. These gases are delivered first to a water wash tank and thence to a soda wash tank, where they are made non-corrosive.

The condensed gasoline is pumped from the bottom of the separator through an emulsion separator which acts as a water and soda washing tank. The acid-free gasoline is taken from the emulsion separator to a combined water separator and reflux tank from which a desired amount is delivered to the top of the fractionating tower as reflux. The quality of the overhead product and stabilized crude oil is controlled by the temperature of the overhead gases and the amount of reflux is governed by the gas temperature. Thus all the fractions which will not vaporize at the temperature and pressure maintained in the top of the tower will pass out with the crude oil at the bottom.

The wet gas at a pressure of 40 lbs. per sq. in. is taken from the top of the soda wash tank, and is compressed to 250 lbs. per sq. in. It is then discharged to a gasoline cooler where partial condensation takes place. The condensates obtained in the gasoline coolers are delivered to an accumulator, previous to being sent to the stabilizing column. The non-condensable gases are delivered to the fuel lines of the refinery.

Light gasoline accumulated in the reflux tank of the crude fractionating unit in excess of that required for reflux is pumped to an intermediate accumulator, where it is mixed with the condensates recovered from the wet gas. The gasoline fractions in the accumulator are pumped to the middle of the stabilizing column, where the lightest fractions are removed.

The liquid passes downward through the column into a reboiler at the bottom and thence into storage tanks or to the refinery's pumps. The liquid removed from the reboiler is a high-grade of blending gas. By proper regulation of reflux temperature and quantity and reboiler temperatures under the operating pressure, the vapor pressure of this blending gasoline can be controlled.

The vapor generated in the reboiler passes into the bottom of the stabilizing tower and upward together with the vapor liberated from the unstabilizing gases. The vapors pass out of the top of the tower into a reflux condenser. The permanent gases from the condenser are delivered to the fuel line of the refinery or to the bottom of the crude fractionating tower in which these gases may be used in stripping. The excess amount of condensate accumulated in the reflux condenser and not needed for reflux in the stabilizing column is drained off into the accumulator tanks and is finally utilized as a bottled liquid gas.

The high-grade blending gasoline obtained from this prestabilizing unit is estimated to pay for most of the cost of prestabilizing the crude. The other savings effected throughout the refinery may be considered as profit and in addition there is the improved marketing value of the final gasoline product.

The Reid vapor is now one of the most important determinations used in the manufacture of motor fuels for plant control. The vapor pressure of a gasoline is an index of its volatility. Research at the Bureau of Standards indicate that the proper volatility of a motor fuel or its ease of starting a cold engine is a problem for the refiner while vapor lock is principally a mechanical problem that can be corrected by proper design of the fuel system.

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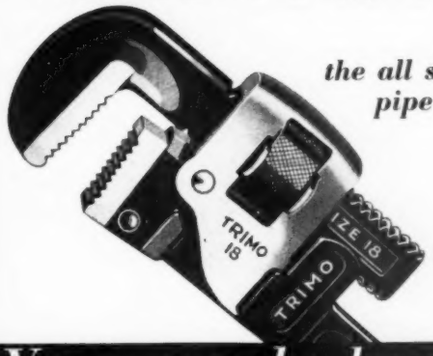

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The Application of Automatic Electric Devices to the Oil Industry

By T. D. WILLIAMSON, E.E.☆

AUTOMATIC devices are becoming more widely used in the oil industry, as the economies which may be affected, and the protection which is afforded, are more thoroughly understood and appreciated.

These devices are, as a rule, quite simple and not radically new; neither are they very expensive. It often occurs that by their use, savings many times the first cost may be effected in a very short time. The devices may be classified as follows: Time control, pressure control and protection, temperature control and protection, liquid level control, and fire protection.

Time Control

During the past two years rapid strides have been made in the development of time switches, until now it is possible to secure a device to meet practically every operating condition and requirements. The three types of operating mechanisms are:

(1) Hand rewound.
(2) Electrically rewound.
(3) Synchronous motor operated.

The first type is the simple old style clock mechanism. Electrically rewound mechanisms include an electric motor arranged to maintain an even tension on the main spring by rewinding every minute, or similar short interval. This equipment may be arranged to operate on either direct current or alternating current service. Synchronous motor operated clocks consist of a small motor, which runs at a constant speed, and is connected direct to the clock gear mechanism. This equipment may be operated only on alternating current circuits, which are "frequency regulated."

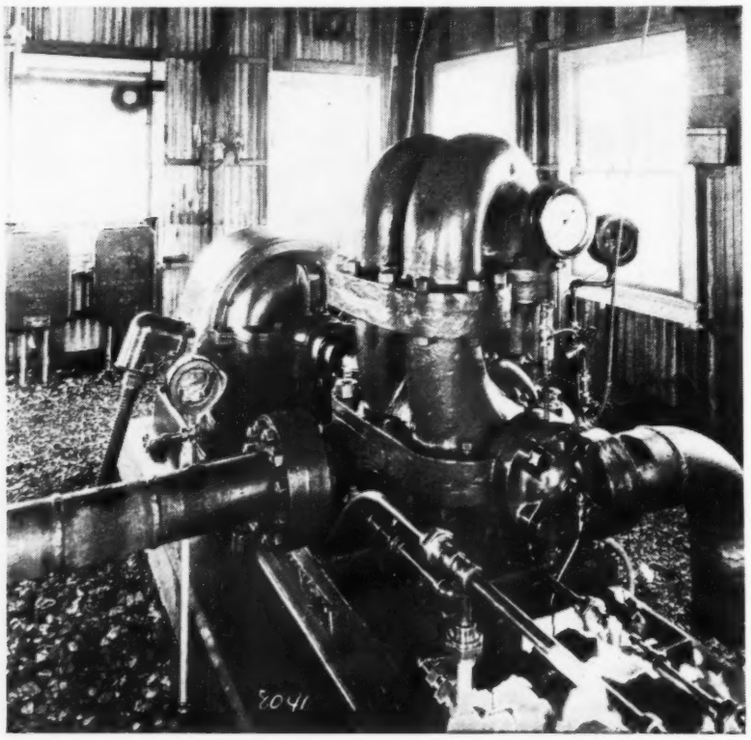
Types two and three have a decided advantage over type one, in that the "human element" is entirely eliminated; the attendant cannot "forget to wind the clock."

The most essential parts of the time switches are the electrical contacts. If these are "open" or air break, they should consist of silver, tungsten or similar metals, which provide a low resistance electric circuit when closed, are not subject to corrosion and will not fuse when the circuit is opened. Mercury tube contacts have been applied to time switches with complete success. This type of contact eliminates most weakness of open contacts, and also provides for complete safety, if the switch is used under gaseous conditions.

Time switches have found numerous applications in the oil industry, some of which are:

(a) Starting and stopping motor driven pumps in pipe line stations.
(b) Starting and stopping motor operated well pumps.
(c) Controlling lighting circuits.

One of the first branches of the industry to adopt time switch control was the pipe line department. Particularly in gathering stations, and small remote plants which operate during specific hours, this device has proven particularly advantageous. In the case of gathering systems, the gauger, after opening the tank valves, sets the time switch for the starting and stopping time of the pump. This time is so arranged that the smallest possible number of motor driven pumps are in operation at the same time, thus reducing the electric demand charge to a minimum, as well as keeping the pressure in the pipe line as low as possible. This latter also results in lower electric cost, since less power is required to pump the oil against the reduced pressure.



Pressure Control Units, in use in an automatic station

In remote booster stations, the motor driven pump is started at the time set on the time switch dial, and the pump is operated for the required time, for which the tripping hand has been adjusted. If electrically rewound or synchronous type switches are used, the station need be visited by the pumper only to inspect the equipment and lubricate the bearings.

In the production department, economic application of time switches has been made to wells remotely located, and which require the attention of individual pumpers. This is particularly true when wells are pumped for a few hours, then shut down for a period of time, and started again. For this application a special type of dial has been developed, which enables the pumper to adjust the settings for as many operations, and as long periods, as may be required. One producing company, through the use of time switches, has been able to greatly reduce the lifting cost per barrel of oil. In this case, too, the wells are alternately pumped for a few hours, stopped for a period of time, and again started.

Through carelessness or neglect, lighting circuits are sometimes left in operation long after

☆Petroleum Electric Co., Tulsa, Oklahoma.

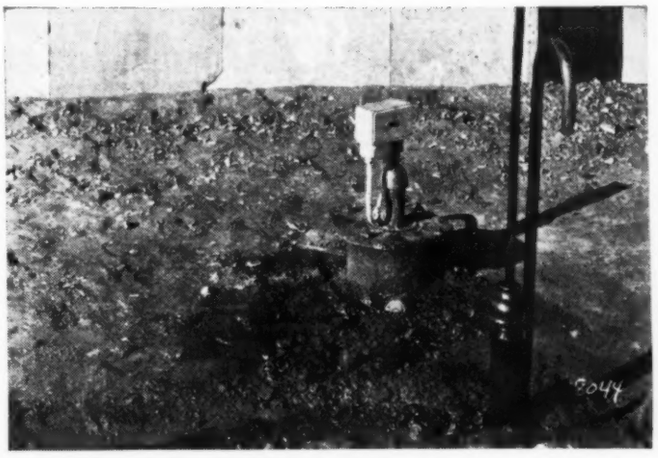
the lights are actually required. The power lost per day may be relatively small, but in the aggregate, and over a period of time this loss may amount to a considerable amount. The use of time switches entirely eliminates this loss, and the cost of the equipment is soon paid for, in the savings effected.

Pressure Control and Protection

With the advent of fully automatic pipe line stations, automatic control of pumping units under varying pressure conditions became imperative. These controls are provided to stop the units due to loss of suction pressure to the station, as well as low pressure conditions on the discharge side of the station. The former condition represents either a broken line between this automatic station and the preceding one, or the stopping of a pump in the preceding station. Low pressure on the discharge side represents a broken pipe line beyond the station.

These protective devices are being used in stations where operators are always in attendance, as an added protection. An operator may be busily engaged at some duty away from the station when a line break occurs beyond the station. Without the use of this protective device many barrels of oil would be lost, during the period before the operator returns to the station. By the use of this device, the station is immediately stopped, or a signal sounded, as soon as the break occurs.

Pressure protective devices are being extensively used in engine driven, as well as motor driven pumping stations. In one application, protection against excessively high pressure is provided, and in case the maximum setting of the device is reached, the ignition circuits of the engines are grounded, and all engines are stopped. Protection is often provided against loss of cooling water and loss of lubricating oil in the engine by means of pressure control units, in either case of which the ignition circuit is grounded and the engine stopped.



Sump Pump Control Unit installed at an automatic pipe line pump station

These pressure devices are designed in accordance with the operating conditions: Low pressure devices have an operating unit consisting of a copper bellows. For high pressure applications, a Bourdon tube is used as the actuating medium. The electric contacts consist of a mercury tube, which is tilted to make and break the electric circuit.

Temperature Control and Protection

Temperature protection devices are applied to motor and pump bearings, pump stuffing-boxes and other parts of the equipments which might become damaged, or cause trouble by becoming excessively hot.

Full automatic pipe line pumping stations require these protective devices, for without an operator in constant attendance, considerable damage might result if excessive temperatures should develop. These temperature protective devices are so connected in the electric control system, that in case of excessively high temperature, the troublesome machine is immediately stopped, and it cannot be started until the difficulty has been remedied.

A number of pipe line companies are equipping their pumps and motors with temperature protective devices, in stations in which operators are in constant attendance. Their reason for this is that the attendant might not detect an improperly lubricated or defective bearing until the temperature became so high that considerable damage had been done. With the protective device, a setting can be made for a temperature slightly above normal, and an alarm would be sounded, or the machine stopped long before damage resulted.

These devices consist of an expansible liquid or gas, encased in a bulb which is in contact with the bearing or portion of the machine to be protected. This may connect directly with the actuating mechanism or through a flexible tube, so the operating mechanism may be located at a distant point. The electric contacts consist of a mercury tube, which is tilted by the operating mechanism to make and break the circuit. The use of this type of contact makes possible the application of these devices in pump rooms, and locations where gaseous conditions exist.

Liquid Level Control

Liquid level control devices are applied to storage tanks—to start and stop motor pump units between predetermined levels, as well as for the control of sump pumps, to replace drainage liquids in the pipe line.

The first fully automatic pipe line pumping station in the Mid-Continent oil fields, consists of a receiving tank, with motor driven pump and liquid level control. When the oil reaches a predetermined high level, the pump is started by the liquid level instrument, and the pump continues to operate until the predetermined low level is reached. This station has been in successful operation for a number of years.

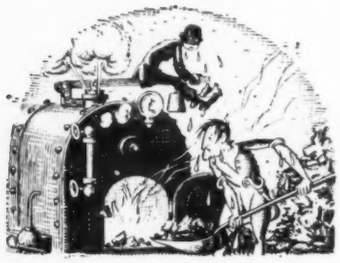
Sump pump control consists of a pressure control unit connected to a two-inch pipe of sufficient length to reach to practically the bottom of the sump. As the sump is being filled, air which is trapped in this two-inch pipe is compressed, and when this air reaches a certain pressure, due to the high level of the liquid, the mechanism within the device is actuated. Conversely, when the liquid is pumped out of the sump, this air pressure is released, and a partial vacuum created, which operates the mechanism in the reverse direction. The electric contacts consist of a mercury tube which is tilted by the actuating mechanism.

Fire Protection

Fire protection has been provided in some pipe line pumping stations by means of a wire, attached to a mercury contact mechanism, and having fusible links located above the points where a fire is most likely to occur. Excessive heat will melt the link, release the wire and allow the mechanism to trip, thus sending an alarm or stopping the station.

A comparatively new control device, which has not, as yet, found many applications in the oil industry, but which in time will have very wide usage, is the "electric eye" or photo-electric tube. This remarkable device, which is operated by changes in the intensity of light, is very sensitive, and may be used to detect changes in colors or shades, within certain limits, and operate control equipment therefrom. Some of the applications in which it might be used in the oil industry are: Counting various operations, grading products, based upon changes in reflecting power; detecting fires, from presence of smoke; and turning on and off lighting systems.

The Fable of
The Rival Towboats



THE steamers Belle and Susie were rival tow boats. In competing for a cargo contract, the Susie won . . . beat her rival's running time on six successive trips. ¶ One day the Susie was delayed. Late arrival meant a heavy penalty . . . the time had to be made up. ¶ To crowd on more steam, her skipper loaded down the safety valve with extra weights. Before long her boilers burst. The emergency had been too great . . . the reserve too small. ¶ He got the contract but he lost his boat.

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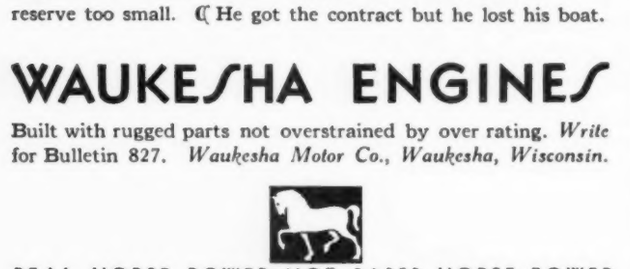

This announcement is addressed to the growing group of men responsible for pipe line condition, who realize the importance of careful selection in protective coatings. There are thousands of miles of inadequately protected pipe line right now which will have to be reconditioned within the next year or two or they will be too far gone to save.

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The Past Year In Na

By EMBY KAYE

THE past year in the natural gasoline industry may hardly be said to have been one of progress. Few plants were built. It is doubtful if any of these were economically justified as gasoline plants. On the other hand, a great number were abandoned, shut down, or salvaged, and, as a result, production took an extraordinary drop. Statistics indicate that there has been a decline in excess of one million gallons, or one hundred twenty-five cars per day. From a peak in 1930 of something short of seven million gallons, today's daily production is reliably estimated at less than four and a half million gallons. It should be pointed out that, included in the current production figure, are variously estimated amounts of super-stabilized gasoline which have found markets as aviation fuels or as direct motor fuels.

The fullest exploitation of vapor recovery plants in refineries has caused a backing up of the supply of natural gasoline in spite of this tremendous reduction in output. As a result, natural gasoline has sold below the cost of manufacture since early 1930 except during a short period in the summer of 1931. It is this unfavorable market price that has driven the natural gasoline manufacturer to seek an independent market for his product.

A large number of plants have been equipped with rectification units to permit the manufacture of gasolines with as low vapor pressure as six and a half to seven pounds. These products must be sold at premiums over U. S. Motor gasoline, and in fact bring premiums, particularly in the winter. Products of higher vapor pressures are sold in competition with motor fuels and are used direct in the winter, and as blending agents during the rest of the year. Naturally, the manufacturer seeks a price in the motor fuel range as it would be to no purpose to stabilize the product at losses of from twenty-five to fifty per cent if the base price were the price of 26-70 natural and the differential only enough to compensate the manufacturer for the loss. Many sales of thirteen pound material and under are based upon 68-70 refinery gasoline. It is indicated that this price structure recognizes the comparative merits of the two products, and takes into account the heavier losses experienced when cutting below a butane-free product.

It is recognized that with present supplies of natural gasoline in relation to the total volume and character of motor fuel from all sources, natural gasoline as such will not ordinarily command a premium over refinery gasoline. With depressed tank car motor fuel prices, a large part of the fair market price of natural, goes to pay the freight to the refinery. It has, therefore, been urged that especially the integrated companies should work out arrangements to blend suitable naturals and refinery stocks to predetermined specifications in as many bulk plans as conditions permit. In integrated companies the savings will be one hundred per cent and in the case of independent jobbers the economies will no doubt be shared by consumer and producer. One need

Natural Gasoline

Skelly Oil Co.

only to make a rough calculation in one's own mind to speculate upon the possible savings for his own company if he figures even only one-half cents per gallon net saving on freight by direct shipment of natural gasoline as against the in and out refinery rate. In my judgment, when this program is in a measure accomplished, it will be the biggest single factor in improving the natural gasoline price situation.

The year has recorded a number of consolidations of plants operating in the same field. Even after a protracted period of unprofitable operation, operators are not without hope and hesitate to discontinue the operation of even the smaller plants. However, companies have done a good deal of trading, have exchanged gas and lines, boosters, etc., in one field for those in another, with the result, that in many cases one plant is operated where two were operated last year, and without affecting the net production of either company. In many cases plants have been allowed to run when they did not actually lose money out of pocket in order to provide employment to men who otherwise would probably have been thrown upon an already over-supplied labor market. It is well that recognition be given this very commendable altruistic policy on the part of many operators, large and small alike.

In October, 1930, issue of *The Petroleum Engineer,* the writer briefly discussed compression and direct-stabilization as a process for gasoline recovery. One such plant had been built in the Kanotex Refining Co.* plant at Arkansas City, Kansas. Another went into operation at Duncan, Oklahoma, early this year. In the Wyoming field the Mid-West Refining Co. converted their large compression plant into such an operation, and here in the Mid-Continent the Gulf Company built a plant of this type in East Texas.

The income of gasoline manufacturers in the Panhandle has been further materially reduced by the decline in price and the subsequent curtailment in production of carbon black. Many plants were justified, when built, upon the carbon black income expectancy. In the last few days the Texas Railroad Commission has issued an order governing the utilization of natural gasoline and casinghead gas which will reduce the production of that field possibly 10 to 15%. Many plants will be shut down, with resulting permanent losses to their owners. Those who have production elsewhere may take what consolation they can find out of the thought that the reduced production will have a tendency to elevate prices.

In the natural gasoline industry the current year will probably not be marked by expansion. Its talents will be expended upon the most effective means for the utilization of its products. The race for production has long been run. The job of today is to control production to meet the demand, in volume as well as in kind. How to make a profit on a declining production, under depressed marketing conditions, is a task to which the best talents of the industry may well be dedicated.

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THE OUTER TUBE

. . with upper valve and lower bushing is the moving part of the pump. The outer tube is maximum size—two inches inside diameter. It is eleven feet and six inches long, which provides for nine-foot stroke.

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. . is stationary and is connected to the hold down connection by steel plunger tube. The plunger valve is fitted with oversize Steelex seat with ball. It is packed with composition cups and a section of special lubricated flax packing. The cups are inverted. As the packing wears, the spring pressure and the fluid pressure keep it expanded to the wall of the outer tube. The pump is regularly furnished with combination (cups and packing) plunger valve as illustrated. Plunger valve with eight cup assembly can be had at no additional cost. Combination plunger valve may be converted into an all cup assembly.

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